NATURAL ENVIRONMENTS FOR TESTING AND TRAINING: DEVELOPING GEOGRAPHIC ANALOGS FOR AN EXPEDITIONARY ARMY

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ABSTRACT

The 21st century Army will be engaged in numerous joint and expeditionary operations throughout the five regional Combatant Commanders' areas of responsibility. Currently, Army forces are deployed globally in more than 120 countries. These regions contain a wide range of natural environments that present unique operational challenges to soldiers and equipment. The distribution of climate, terrain and other environmental factors, and their potential effects on Army operations, must be fully understood. There is a direct geographical and physical relationship between *where* the Army trains soldiers and tests equipment at U.S. installations to *where* it will deploy its forces. The conduct of any military enterprise is conditioned by the character of the area of operations--the military operating environment (Palka and Galgano, 2005). Military history and military geography, as well as lessons learned from current operations, provide ample evidence that understanding and adapting to the natural environment is a critical component of operational success.

A revised framework for understanding the natural environments of operational areas, and their relationships to U.S. training and testing installations, is presented. This framework – the Global Military Operating Environments (GMOE) – is developed from a world-wide ecoregional classification system that provides a logical and scientifically based approach to characterizing the spatial distribution of climates and associated environmental factors. The GMOE framework allows for comparison of operational environments across the globe to those found on U.S. Army installations where training of soldiers and testing of equipment take place.

1. INTRODUCTION

In order to meet current and future operational demands the Army is rapidly rebasing and transforming its installations, units and war fighting doctrine to meet the demands of a new strategic reality. The Capstone Concept for Joint Operations (CCJO) describes how future joint forces are expected to operate across a broad spectrum of military operations in 2012-2025 in support of strategic objectives. (U.S. Department of Defense, 2005). Emerging and potential threats from transnational actors, regional and emerging global competitors and failed states present a complex, multi-dimensional system of adversaries and situations across the globe to which our forces must adapt. In his visionary book, *The Pentagon's New Map,* Thomas Barnett defines a global region, the Non-Integrating Gap, where the majority of conflicts, disasters and military deployments have occurred over the past fifteen years (Barnett, 2004). These conflict areas include the equatorial and mid-latitudinal regions of the Caribbean Rim, Africa, the Balkans, the Caucasus, Central Asia, the Middle East, Southwest Asia and Southeast Asia. The Gap regions lie outside the Functioning Core countries and regions of North America, Europe, East Asia and Australia, and are

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characterized by diverse natural settings where environmental conditions – disease, famine and poverty induced by natural disasters and resource exploitation – often contribute to the rise of conflict. King (2000) assessed the environmental issues in many of these Gap regions that pose national security concerns for the future and concluded that most environmental security issues are regional in nature and within the domain of the regional Combatant Commanders.

These future scenarios will take place amidst a wide range of natural and built environments that will shape the operational space and require soldiers and units to adapt to the associated climate, weather and terrain of these operational environments. As the nation's major land force the Army must organize, train and equip its soldiers and units to go anywhere in the world, against any adversary, at any time, in any environment. Current deployments associated with the Global War On Terrorism (GWOT) and military support to stability, security, transition and reconstruction (SSTR) operations throughout Southwest Asia, Central Asia, Africa, Indonesia and Central/South America present Army forces in those theaters with a complex range of natural environments, ranging from remote and austere arid regions to rugged, snow covered mountains and dense tropical jungles. For each campaign it must consider more fully how the natural environment will affect operational success.

The Army's existing frameworks and approaches to characterizing the natural environment worldwide are outdated, oversimplified, and lack scientific underpinnings. Like Barnett's strategic and economic theories on how and why the Core and Gap regions developed, an integrated set of organizing principles and rule sets are needed to delineate the geographic boundaries and distributions of natural environments on the continental land masses. Many of the geographic concepts used in doctrinal training manuals and testing regulations preceded the Army's current expeditionary context and mindset. These concepts generalize operational environments into broad, undifferentiated landscape categories - "jungle," "mountains," and "deserts," or into broad climatic regions such as "cold," "hot," "wet" and "dry." These categorizations focus on the "extremes" in climate and terrain and ignore the complexity and variability of environments found within mid-latitudinal environments where many recent and future conflicts may occur.

Thus, a new framework and approach to define natural operating environments worldwide is needed to support the Army's contemporary operating environment and expeditionary focus. This framework should explain why certain environments occur in predictable and spatially defined patterns across the continents. Understanding these patterns and the interrelationships between climate, vegetation and topography can provide insights into when and where physical phenomena affecting operations may occur. Secondly, the framework should allow for comparison and contrast between existing training and testing environments on installations in the United States and similar environments, or analogs, found world-wide. The importance of identifying and sustaining unique environments in the Army's training and testing land inventory is critical as the Army continues to train and test as it fights.

2. GLOBAL MILITARY OPERATING ENVIRONMENTS

In order to address these deficiencies a panel of military scholars, environmental scientists and federal researchers was organized to study how operational environments could best be characterized for testing and training scenarios. The panel conducted studies on tropical and desert environments to identify the ideal physical and environmental characteristics that represent these operational environments (King, et al., 1998; King, et al., 2004). As a component of these studies the panel recognized the need to develop a scientifically-based, comprehensive framework that could be used to characterize the world's natural environments and be applied to Army training and testing applications. The resulting framework, entitled Global Military Operating Environments (GMOE), integrates mean annual and monthly climatic data on temperature and rainfall with other physical characteristics (e.g., vegetation, terrain and soils), using an integrated, ecoregional based classification system. The GMOE approach is hierarchical and divides the earth's land surface into regions defined by common climatic and physical characteristics.

The GMOE classification scheme is derived from Robert G. Bailey's ecoregional classification system (Bailey, 1998a). This system is used extensively by federal, state and regional agencies for environmental planning, research and analysis. The primary factor used in Bailey's system to classify an ecoregion is climatic regime, defined as the seasonality of temperature and precipitation. The global distribution and patterns of climatically-similar environments depend broadly upon large-scale climate controls. These controls include: latitude, continental position, global atmospheric patterns and oceanic circulation patterns. The presence of major mountain ranges further modifies this distribution and pattern.

Ecoregions are large, regional-scale ecosystems. Climatic parameters are used to establish ecoregional differences; however, no attempt is made to use the climatic parameters to establish boundaries. Instead, climatic differences are inferred where discontinuities appear in physiography (e.g., where flat plains change to mountains) and/or vegetation physiognomy (e.g., where tall grass prairie changes to short-grass steppe or

savanna.) In other instances, geological boundaries are used because different types of geology override the climatic effect (Bailey, 2005).Generally each climate is associated with a single vegetation class (such as broadleaf deciduous forest), characterized by a broad uniformity both in appearance and in composition of the dominant plant species.

Bailey's ecoregional classification system divides the Earth's land surface into three different hierarchical classes, *Domains, Divisions* and *Provinces*. Each category of the classification system can be mapped across the Earth at different geospatial scales on the basis of specific environmental criteria. Depending on the selected geospatial scale, the defined classes are designed to exhibit similar patterns in: (i) climate, (ii) vegetation, (iii) topography and landform, (iv) hydrologic function, and (v) soils. For example, as shown in Table 1, *Domains* and *Divisions* are recognized at the 1:30,000,000 scale to 1:7,500,000 scales (Bailey, 1998). At the *Province* level the macro features of associated vegetation types are used to further distinguish climatic differences. At both the Division and Province levels, mountainous regions are distinguished from their surrounding lowland classification because mountain climates are vertically differentiated, based upon the temperature and precipitation changes that occur with altitude (Bailey, 1998). For example, a high mountain range (e.g., 4,000 meters elevation) located at an equatorial latitude may exhibit several climatic zones from its base to its peak, with associated vegetation types, ranging from tropical to subarctic.

Table 1. Criteria and Scale for Mapping Bailey's *Domains* and *Divisions* (See Note)

Category	Principal Map Criteria	Map Scale	Map Area of Coverage
Domain	Broad climatic zones or groups	1:30,000,000 or smaller	1,000,000s of square miles
Division	Regional climatic types; major mountain ranges; vegetation affinities (e.g. prairie or forest); soil orders	1:30,000,000 to 1:7,500,000	100,000s of square miles

(Note: the degree of map detail and resolution increases as the map scale ratio (1:x or 1/x) becomes larger – e.g., a 1:7,500,000 scale map provides four times more detail than a 1:30,000,000 scale map)

Domains constitute the four principal sub-continental regions of closely-related climatic zones. These macro-environments comprise land areas of related climates that are characterized by broad differences in latitudinally-controlled annual temperature, precipitation, and evapotranspiration. Three domains are humid and differentiated on the basis of their thermal character: Polar with no warm season; Humid Temperate, rainy with mild to severe winters; and Humid Tropical, rainy with no winter season. The fourth, Dry, is defined solely on the basis of moisture and transects the otherwise humid climates.

Divisions are the second-order classes recognized on the basis of the seasonality of precipitation or degree of dryness or cold. The *Divisions* correspond to groups of specific climate as determined by regions of vegetative similarity (e.g. rainforest, tundra) within the same zones of regional climate. The climate is not completely uniform within each *Division*. For example, there is a wide range of aridity within dry climates, ranging from very dry deserts through areas with transitional levels of moisture in the direction of the adjacent moist areas. As previously discussed, each *Division* (less the Icecap Division) has a corresponding mountainous equivalent to distinguish vertically differentiated climates.

In adapting Bailey's system for the Army, fifteen distinct categories are used to delineate and characterize the types of natural environments in which Army operations potentially will take place. While the existence and effects of mountainous regions on military operations are fully recognized, the mountain categories, as defined by Bailey, have been incorporated into the corresponding adjacent "lowland" category for this level of analysis.

The *Global Military Operating Environment (GMOE)* system connotes the specific application to military operations worldwide. Figure 1 illustrates the worldwide distribution of the GMOEs. Table 2 illustrates the percentage distribution of the fifteen GMOEs on a worldwide basis:

Table 2. Distribution of World Ecoregions by Division (GMOE) and Domain

Division/GMOE Category	% of World Acreage- Bailey's Division/GMOE	% of World Acreage - Bailey's Domains
Icecap	10%	27% Polar
Tundra	4%	
Subarctic	13%	
Warm continental	2%	16% Humid Temperate
Hot continental	2%	
Subtropical	4%	
Marine	2%	
Prairie	4%	
Mediterranean	2%	
Tropical/Subtropical Steppe	10%	30% Dry
Tropical/Subtropical Desert	14%	
Temperate Steppe	2%	
Temperate Desert	4%	
Savanna	17%	27% Humid Tropics
Rainforest	10%	

Three GMOE are defined within the ***Polar Domain***: the *Icecap*, dominated by permanent ice sheets (e.g., Greenland and Antarctica), the *Tundra* where the average annual temperature of the warmest month lies between 0-10°C, and the *Subarctic*, where only one month each year has an average temperature above 10°C.

The ***Humid Temperate Domain*** is divided into six GMOEs based upon distinct combinations of winter and summer temperatures. The *Warm Continental* is characterized by very cold, snowy winters and warm summers, the *Hot Continental* has cold winters and hot summers, and the *Subtropical* is rainy and characterized by mild winters and hot summers. The *Prairie* is classified as a sub-humid area that is transitional between dry and humid climates. The *Mediterranean* has dry, hot summers and rainy, warm winters, whereas the *Marine* is characterized by rainy, mild winters and warm summers.

The ***Dry Domain*** can be partitioned into very arid areas (deserts) and semi-arid areas (steppes) that separate arid regions from those of humid climate. Four GMOEs are defined: the *Tropical/Subtropical Steppe* is a large semi-arid zone with tropical deserts to the north and south; the *Temperate Steppe* is characterized by a semi-arid continental climate with cold winters and warm to hot summers; the *Tropical/Subtropical Desert* is characterized by extremely arid conditions with high air and soil temperatures and the *Temperate Desert* is arid with hot summers and cold winters.

In the ***Humid Tropics*** which contains two GMOEs,

there is no winter season and each month of the year has an average temperature above 18°C. The *Savanna* has distinct wet and dry seasons that lead to the development of tall grasslands that contain drought-tolerant shrubs and trees. The *Rainforest* is located astride the Equator, ranging between 10°N and 10°S latitude and has a wet equatorial climate with no distinct dry season.

3. REGIONAL AREAS OF RESPONSIBILITY

The five regional Combatant Commanders are responsible for the allocation of joint forces to meet the national defense security objectives and missions (U.S. Department of Defense, 2005). Figure 2 depicts the geographic boundaries associated with these areas of responsibility (AOR). Table 3 identifies the occurrences of the fifteen GMOEs within each AOR. With the exception of USCENTCOM, the majority of GMOEs are found within each Combatant Commander AOR. While the percentage area of each GMOE within a given AOR varies considerably, this distribution emphasizes the need for joint and Army forces to be trained in a wide variety of natural environments and to ensure that testing of equipment occurs in multiple environments.

4. ARMY INSTALLATION ANALOGS

The Army manages a diverse installation inventory in the U.S. and at forward basing areas to train its forces and test its equipment prior to deployment (Shaw, et. al., 2000; Doe, et al., 1999). The ability to conduct pre-deployment activities in similar natural environments and settings is critical to mission success. For example, the importance of the Army's National Training Center (NTC), in the Mojave Desert of California, and the Army's Yuma Proving Ground (YPG) in the southwestern desert region of Arizona, as locations to prepare and test units and equipment for extended operations in similar arid environments is well documented. Similarly, Army installations in Alaska and Hawaii provide training and testing capabilities in preparation for deployments to mountainous, cold regions and tropical environments found on other continents. Despite the "geographic analogs" provided by these installations many future conflict and disaster areas may differ significantly in terms of climate, physiography and other environmental parameters.

Table 4 displays the locations of thirty six major U.S. Army installations in the United States and their corresponding GMOEs. These installations were selected because they constitute the largest (by area) of the Army's installations and because in some cases, they represent the sole installation found within a particular GMOE. As indicated there are numerous Army installations that reside within the hot continental and subtropical climates and which therefore, are similar in their physical characteristics to major conflict areas

(Russia, Kazakhstan, Georgia, Turkey, Afghanistan, China, Korea, etc.). Areas of tropical/subtropical and temperate deserts (Iraq, Iran, Sudan, Egypt, Algeria), where conflicts are occurring, are also well represented by Army installations. However, this comparison also reveals a significant lack of adequate training and testing land resources that represent potential conflict areas in the Mediterranean, savanna and tropical environments.

CONCLUSIONS

The Global Military Operating Environments (GMOE) system, as adapted from Bailey's ecoregional classification scheme, provides a world-wide, scientifically-based framework to assess the natural environments of current and future deployment areas. The map of GMOEs illustrates the pattern and distribution of similar environments within the five Combatant Commanders' areas of responsibility (AOR). The framework also allows for comparison of Army training and testing installations as "analogs" to operational areas. Detailed, site specific studies, using available digital data and remotely sensed sources, within each of the fifteen GMOEs, at both the installation level and operational area level, are needed to more fully understand potential influences and effects of the natural environment.

ACKNOWLEDGMENTS

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Table 3.	Regional Combatant Commanders' Areas of Responsibility [*] (* See Figure 2)				
Global Military Operational Environments	**USCENTCOM**	**USEUCOM**	**USPACOM**	**USNORTHCOM**	**USSOUTHCOM**
Icecap		X	X	X	
Tundra		X		X	
Subarctic		X		X	
Warm Continental		X	X	X	X
Hot Continental		X	X	X	
Subtropical	X	X	X	X	X
Marine		X	X	X	X
Prairie		X	X	X	X
Mediterranean		X	X	X	X
Tropical/Subtropical Steppe	X	X	X	X	X
Tropical/Subtropical Desert	X	X	X	X	X
Temperate Steppe	X	X	X	X	X
Temperate Desert	X			X	X
Savanna	X	X	X	X	X
Rainforest		X	X	X	X

Table 4. U.S. Army Installation Analogs of Global Military Operating Environments

Global Military Operating Environments	Major Army Installation Analogs						
Subarctic	Fort Wainwright, AK	Fort Richardson, AK	Donnelly TA, AK				
Warm Continental	Camp Grayling, MI						
Hot Continental	Fort Knox, KY	Fort Benning, GA	Fort Leonard Wood, MO	Fort Campbell, KY	Fort Drum, NY	Camp Ripley, MN	Fort McCoy, WI
Subtropical	Aberdeen PG, MD	Fort Bragg, NC	Fort Stewart, GA	Fort Polk, LA	Fort Rucker, AL	Fort Jackson, SC	Fort Gordon, GA
Marine	Fort Lewis, WA						
Prairie	Fort Riley, KS						
Mediterranean	Fort Hunter Liggett, CA						
Tropical/Subtropical Steppe	Fort Sill, OK	Fort Hood, TX					
Tropical/Subtropical Desert	Fort Irwin, CA	Fort Bliss, TX	Fort Huachuca, AZ	White Sands Missile Range, NM	Yuma Proving Ground, AZ		
Temperate Steppe	Fort Carson, CO	Pinyon Canyon Maneuver Site, CO					
Temperate Desert	Yakima Training Ctr, WA	Dugway Proving Ground, UT	Orchard Training Area, ID				
Savanna	Camp Santiago, Puerto Rico						
Rainforest	Schofield Barracks, HI	Pohakuloa Training Area, HI					

Figure 1. World Distribution of Global Military Operating Environments

Global Military Operating Environments

Icecap	Warm Continental	Marine	Tropical/Subtropical Steppe	Temperate Desert
Tundra	Hot Continental	Prairie	Tropical/Subtropical Desert	Savanna
Subarctic	Subtropical	Mediterranean	Temperate Steppe	Rainforest
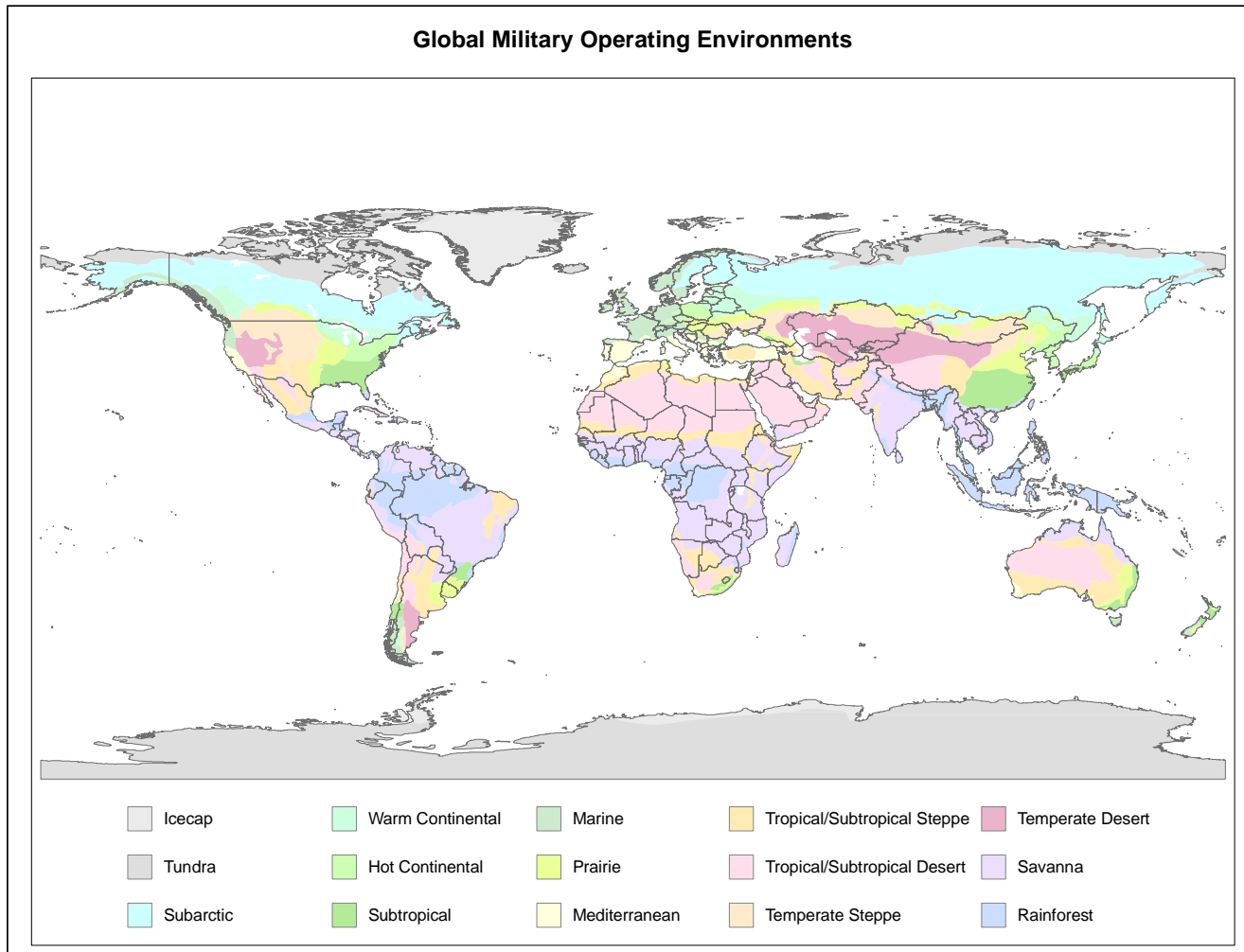
Figure 2. Regional Combatant Commanders' Areas of Responsibility (AOR) superimposed on Global Military Operating Environments
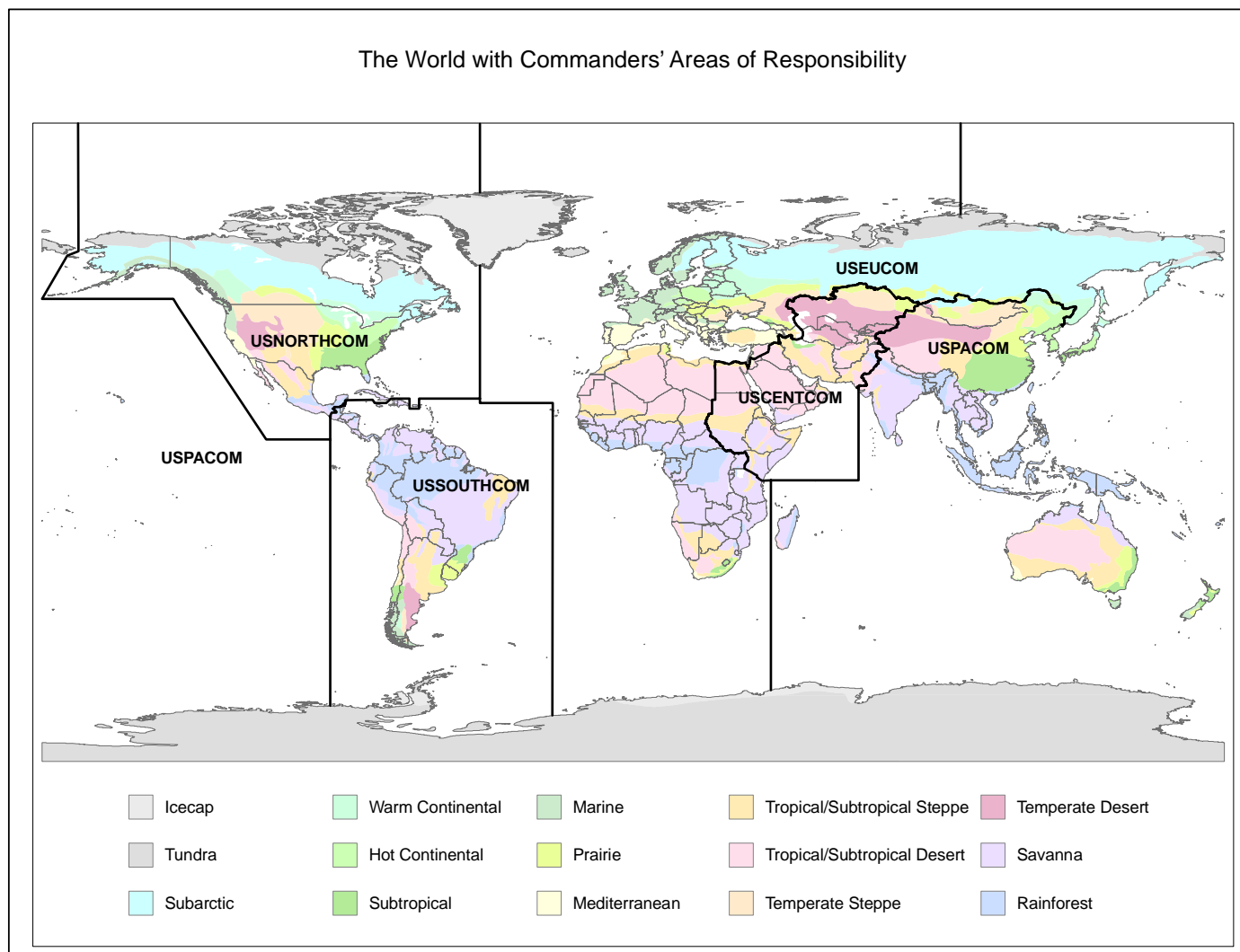
The World with Commanders' Areas of Responsibility

USEUCOM
USNORTHCOM
USPACOM
USCENTCOM
USPACOM
USSOUTHCOM

Icecap	Warm Continental	Marine	Tropical/Subtropical Steppe	Temperate Desert
Tundra	Hot Continental	Prairie	Tropical/Subtropical Desert	Savanna
Subarctic	Subtropical	Mediterranean	Temperate Steppe	Rainforest

Natural Environments for Testing and Training:

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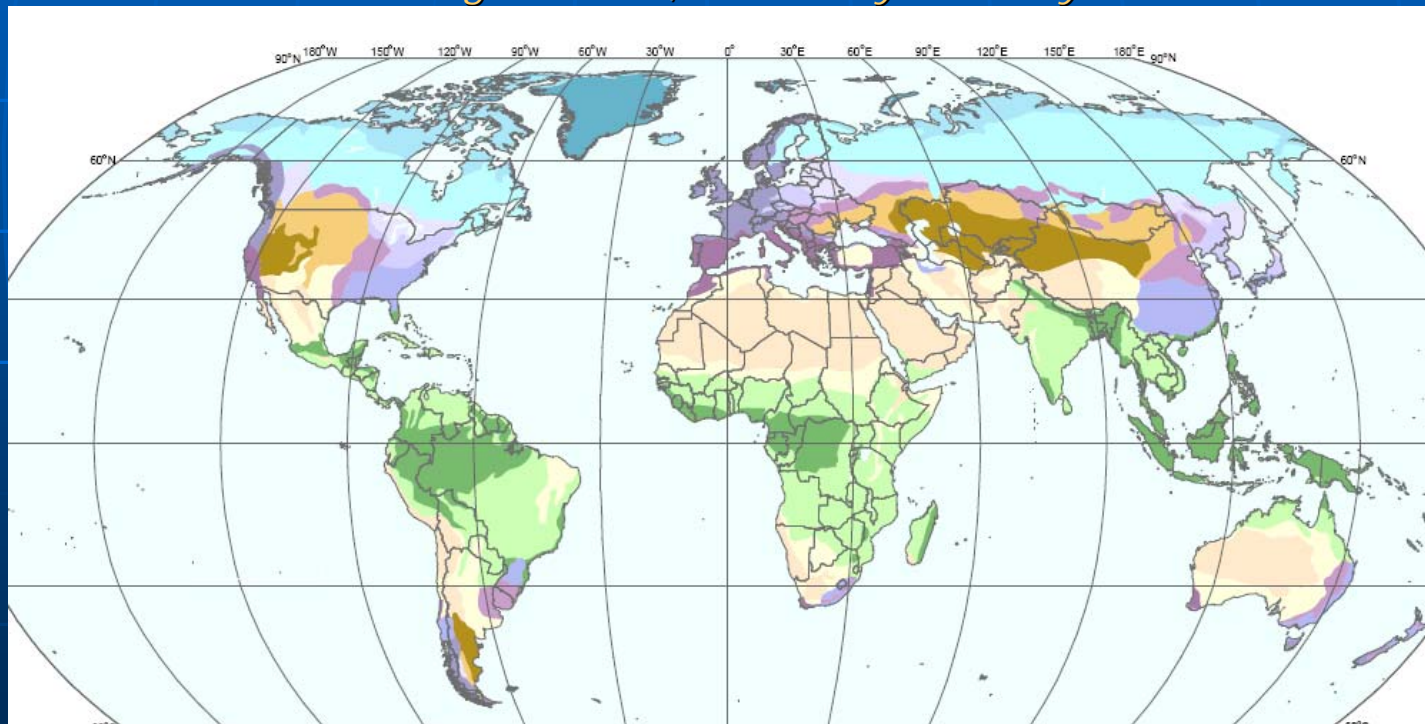
Introduction

- Tenet of Army warfighting doctrine is to "train as it fights" – understanding the natural environment and its potential effects on Army operations is a key component of operational success

- Tenet of Army RDT&E requirements is to test materiel and equipment under conditions which replicate the range of climatic and physical environments anticipated for their use

- The expeditionary Army of the 21st century will operate world-wide within new and complex natural environments

Presentation Outline

- Natural Environments of Combatant Command Regions
  - New geographical threats and areas of concern
- Environmental characterization of the natural environment
  - Physiographic (terrain) studies of operational areas by Army Corps of Engineers (WWII, Vietnam Conflict)
  - Explosion of high-resolution digital data (remote sensing, geographic information systems)
  - Development of new, integrated spatial frameworks from ecological science to better understand climatic and landscape patterns
- Analogs of U.S. Army installations – deployment areas
  - Where the Army tests and trains in the U.S.
  - Lack of adequate Army analogs for some environments

Army Scientific Panel – Global Military Operating Environments (GMOE)

- Panel of military, federal and academic scientists to advise and complement internal Army agency efforts to address future needs for natural environments testing

- Integrate scientific knowledge of the physical environment with operational requirements for testing of Army materiel and equipment

- Environmental characterization studies of current inventory of Army testing installations as analogs

- Information and approach has application to Army training installations to determine adequacy of U.S. Army installation inventory to represent current and future conflict environments

Bailey's Ecoregion Classification System

- Scientifically based, integrated system for mapping and describing natural environments
- Developed and expanded by the USDA/Forest Service in 1993 as the classification system to be used in federal land ecosystem management
- Used for ecological classification of U.S. Army installations in 1999-2002
- Has been applied to both the United States and Worldwide for a wide range of environmental applications
- References:
  - *Robert G. Bailey, Ecoregions: The Ecosystem Geography of the Oceans and Continents (1998), Springer Press.*

Bailey's Ecoregion Classification System

- **Hierarchical classification system which can be applied at various mapping scales (macro to micro) and level of detail**
  - **3 levels/categories in the hierarchy:**
    - **Domains (4)**
      - **Divisions (15)**
        - **Provinces (86)**

- **Boundaries of regions determined by climatic controls (latitude, continental position, ocean currents, elevation) and their tangible expression to macro-vegetation formations**

- **Similar (analagous) ecoregions occur in predictable locations on different continents**

- **Data from one ecoregion can be extended to similar ecoregions on other continents**

- **Similar patterns of climate and landscape can be expected on different continents**

Pattern of Ecoregions Distribution on Continents

Pattern of Ecoregions on a Hypothetical Continent of Low, Uniform Elevation

Global Military Operating Environments - World Distribution by Division
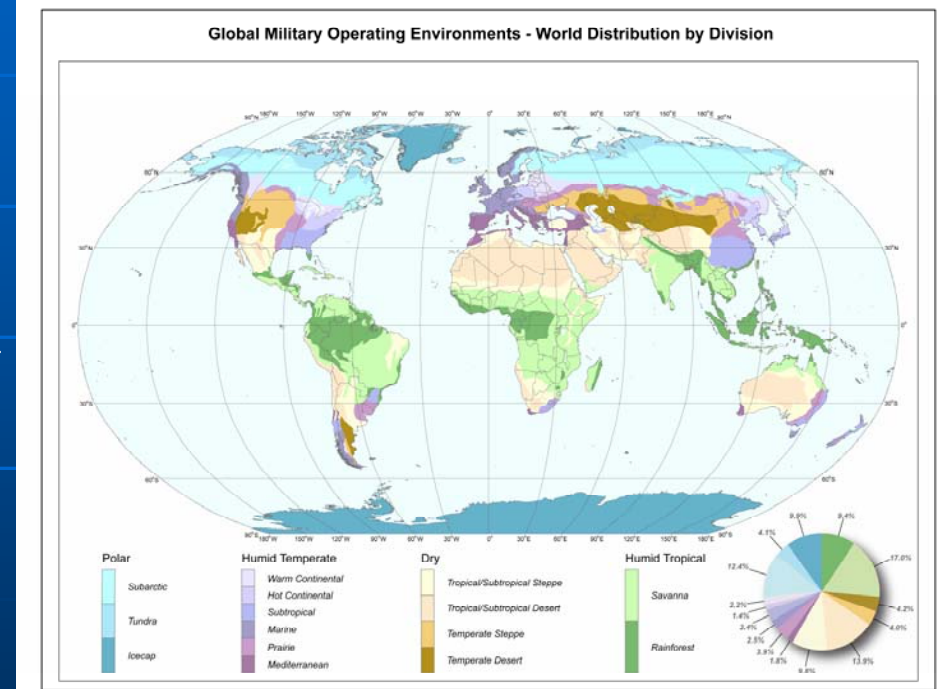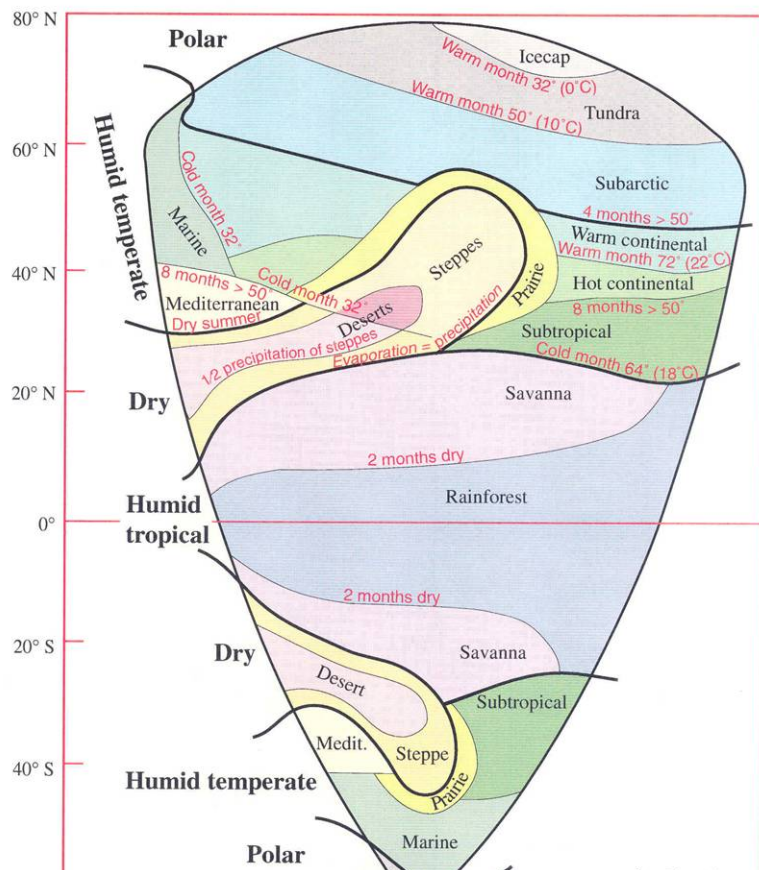
Hypothetical patterns of ecoregions are modified by latitudinal position and size of the actual continental land masses

Climograph Description
(Temperature and Precipitation Regimes)
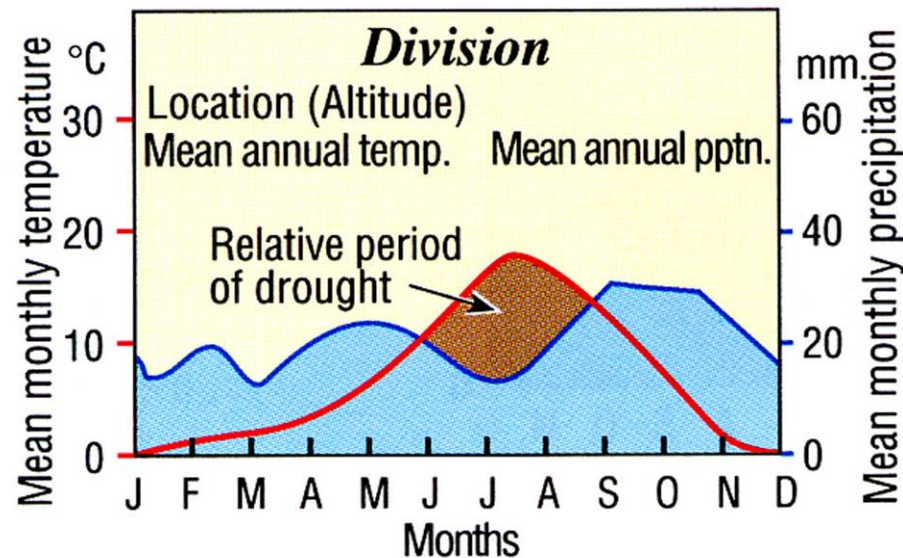
The climate of a location/region is determined by the annual range (high to low), distribution (seasonality) and relationship between temperature and precipitation over a long period of record. The climate is a primary determinant of a location's vegetation formations, soil types and landscape characteristics.

Global Military Operating Environments - World Distribution by Domain
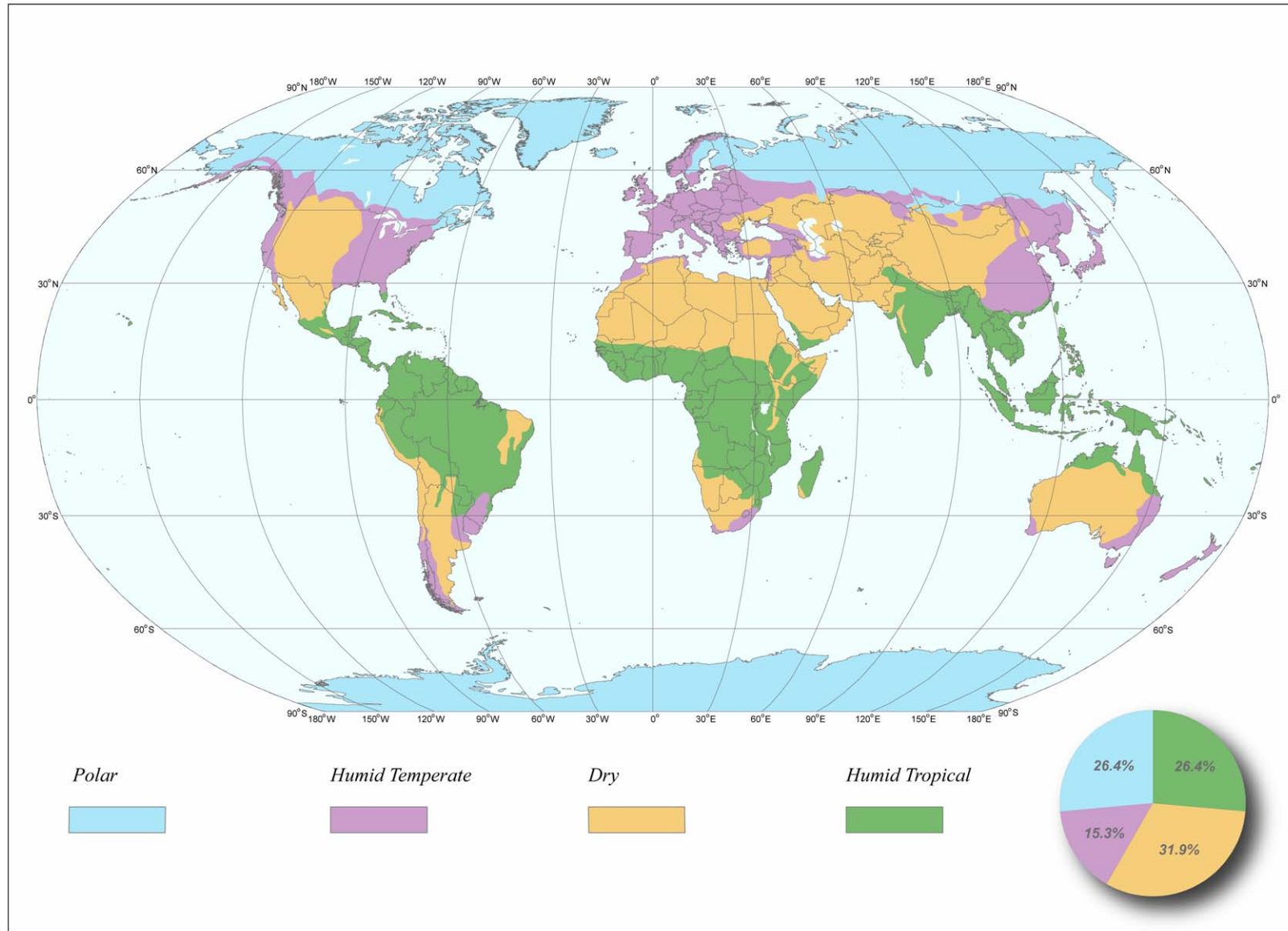
Global Military Operating Environments - World Distribution by Division
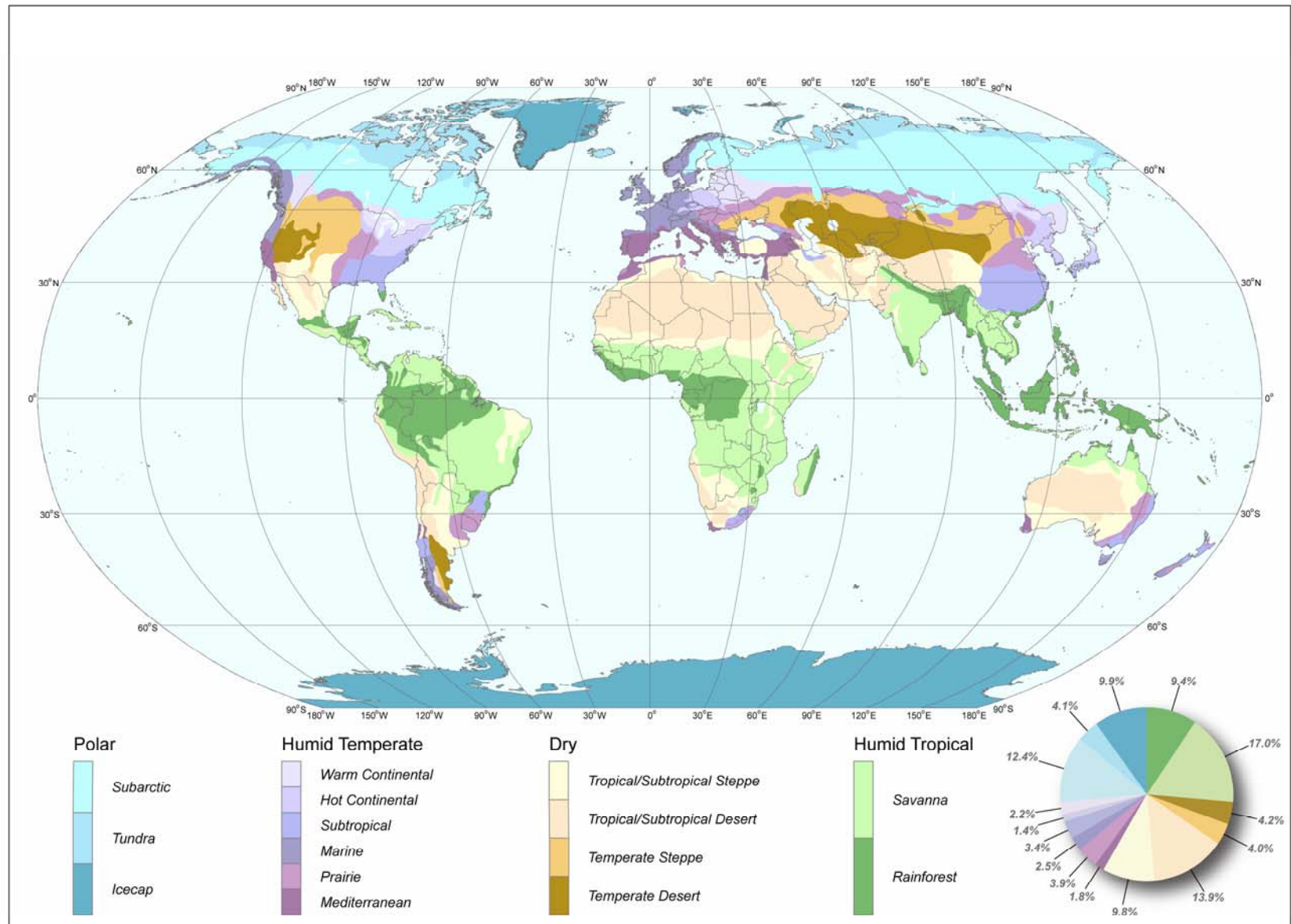
Emerging Threat Environments

- The "Pentagon's New Map"
  - Thomas Barnett's "Functioning Core" vs. "Non-Integrating Gap" Regions
  - Functioning Core areas:
    - Humid temperate, Mediterranean environments (North America, Europe, China)
  - Equatorial and mid-latitudinal conflict areas:
    - Dry (desert/steppe) environments
    - Humid tropical (rainforest/savanna) environments
- Environmental conditions and lack of natural resources create "environmental security" driven conflicts

Global Military Operating Environments - Combatant Commanders' Areas of Responsibility
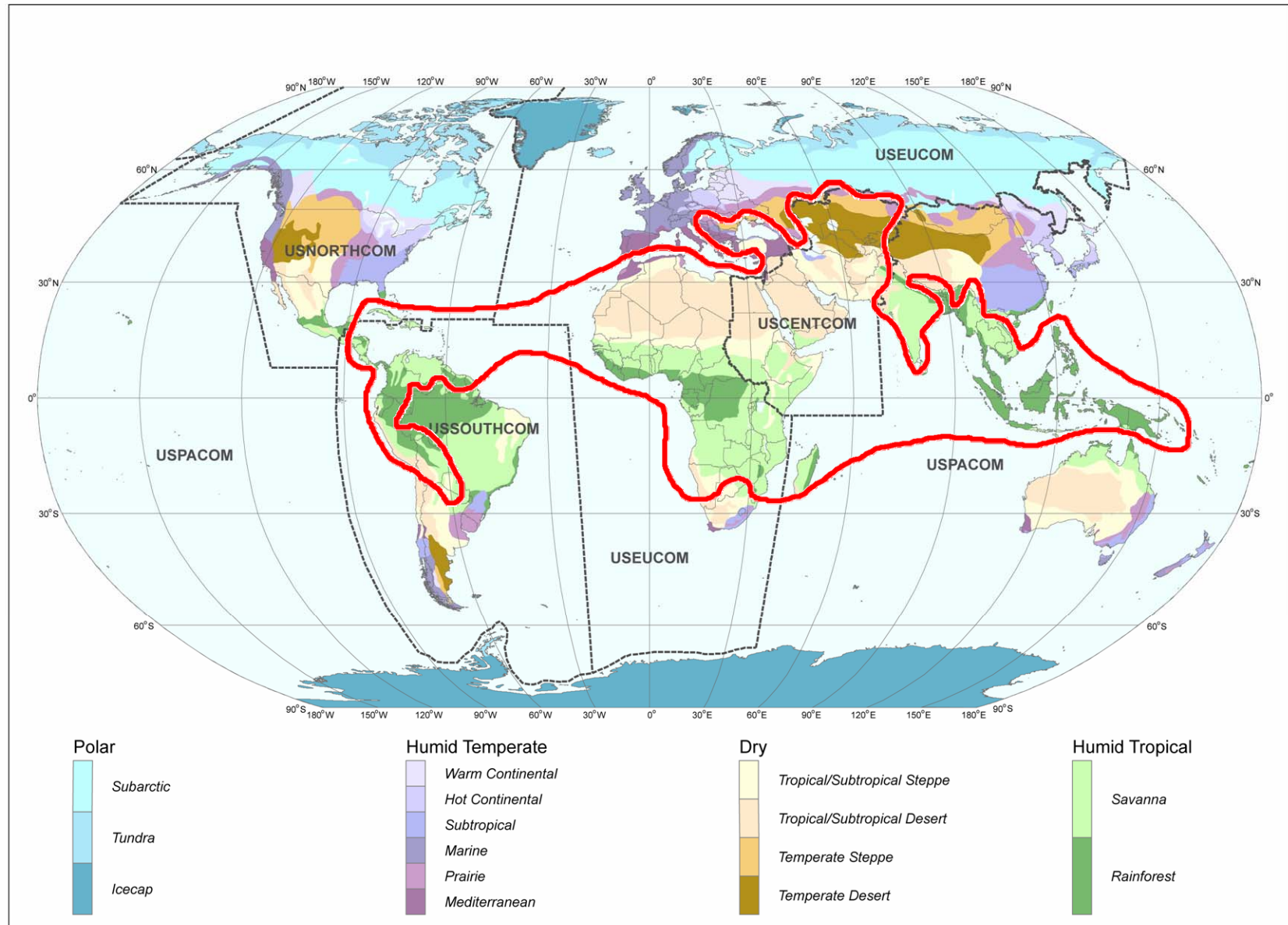
USSOUTHCOM: Distribution of Regional Environments
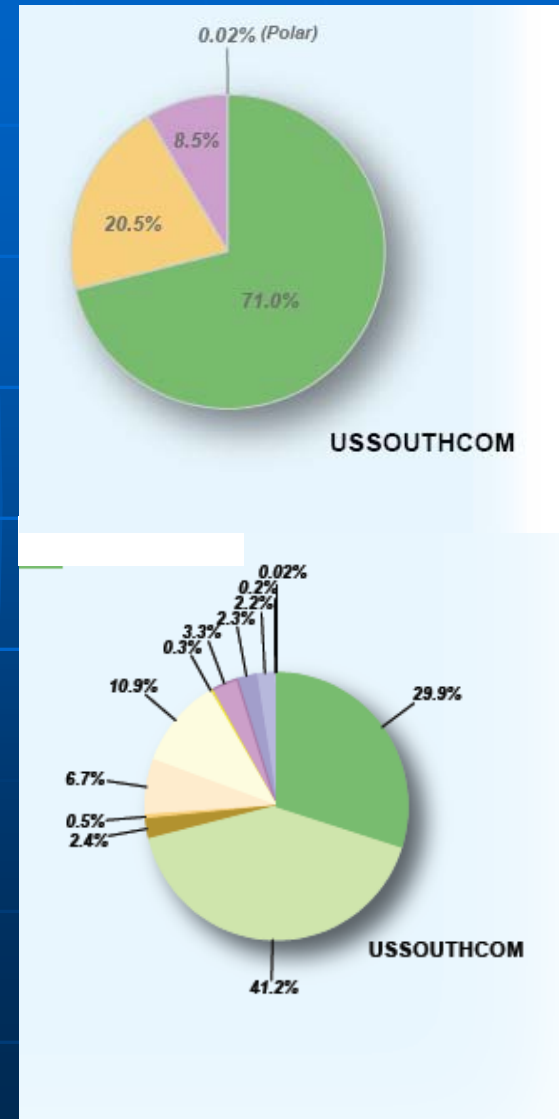
USEUCOM: Distribution of Regional Environments
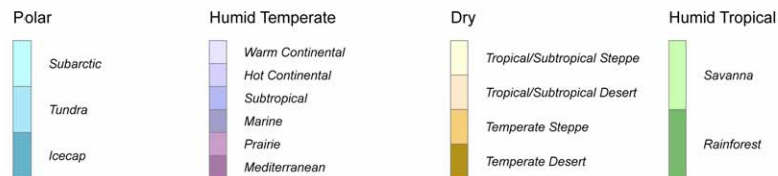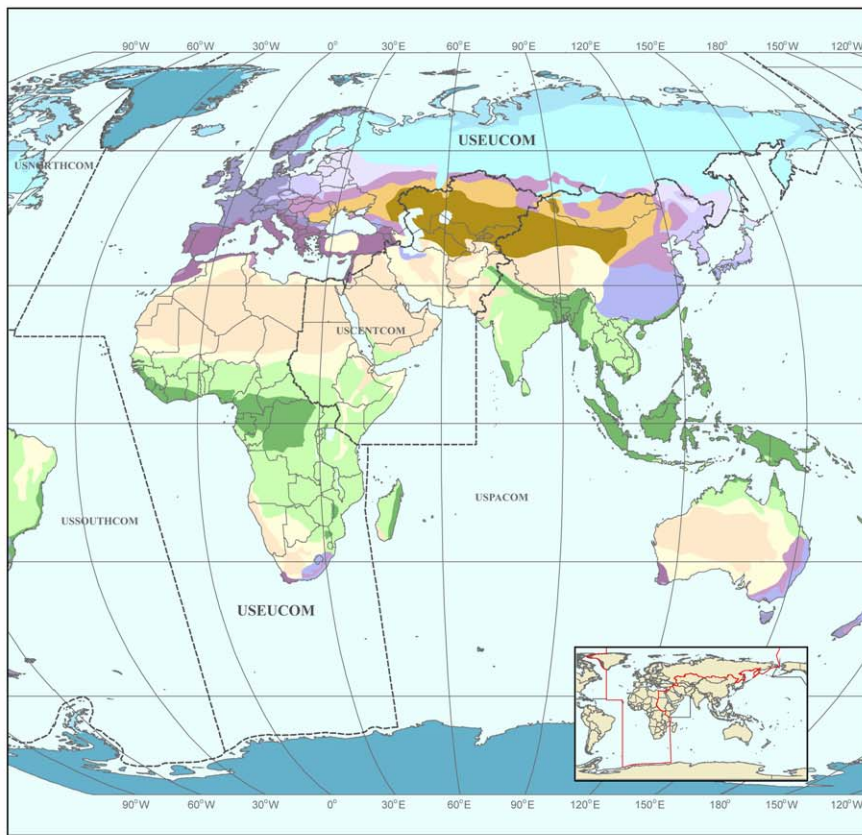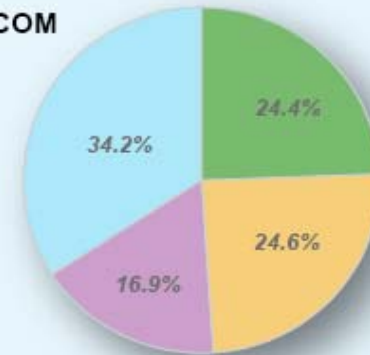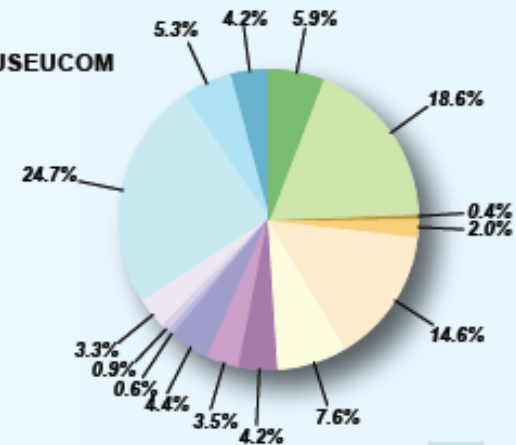
USCENTCOM: Distribution of Regional Environments
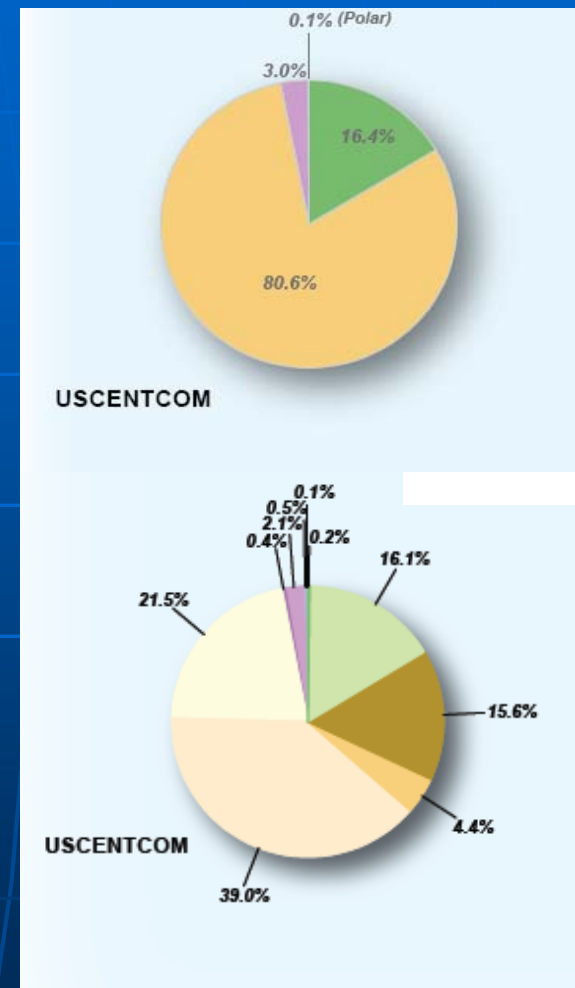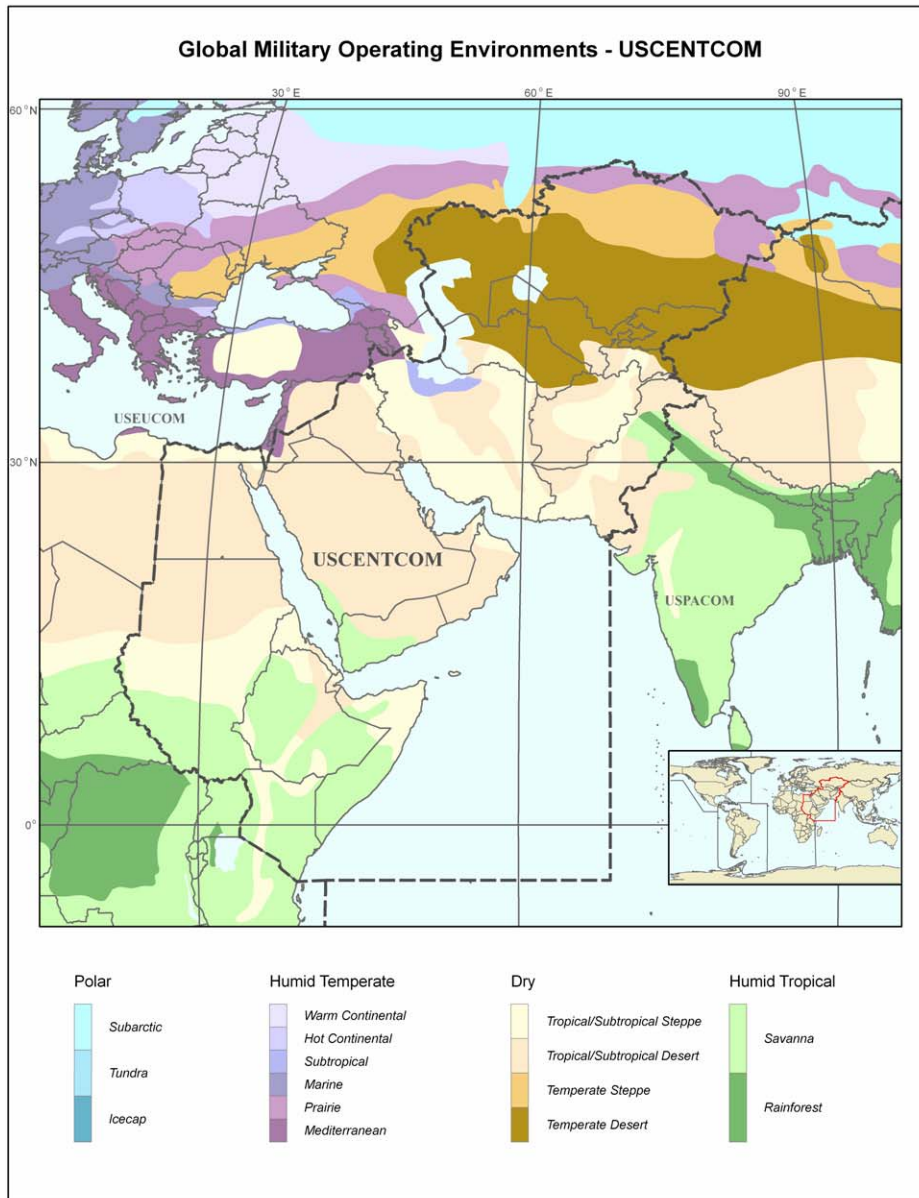
USPACOM: Distribution of Regional Environments
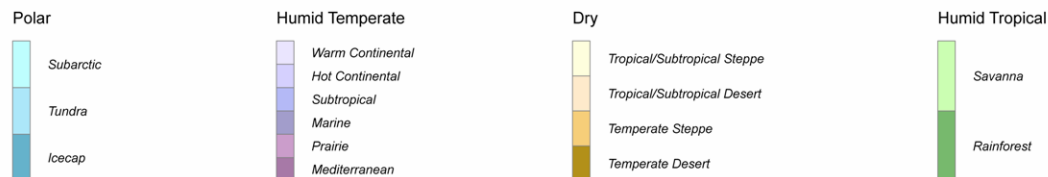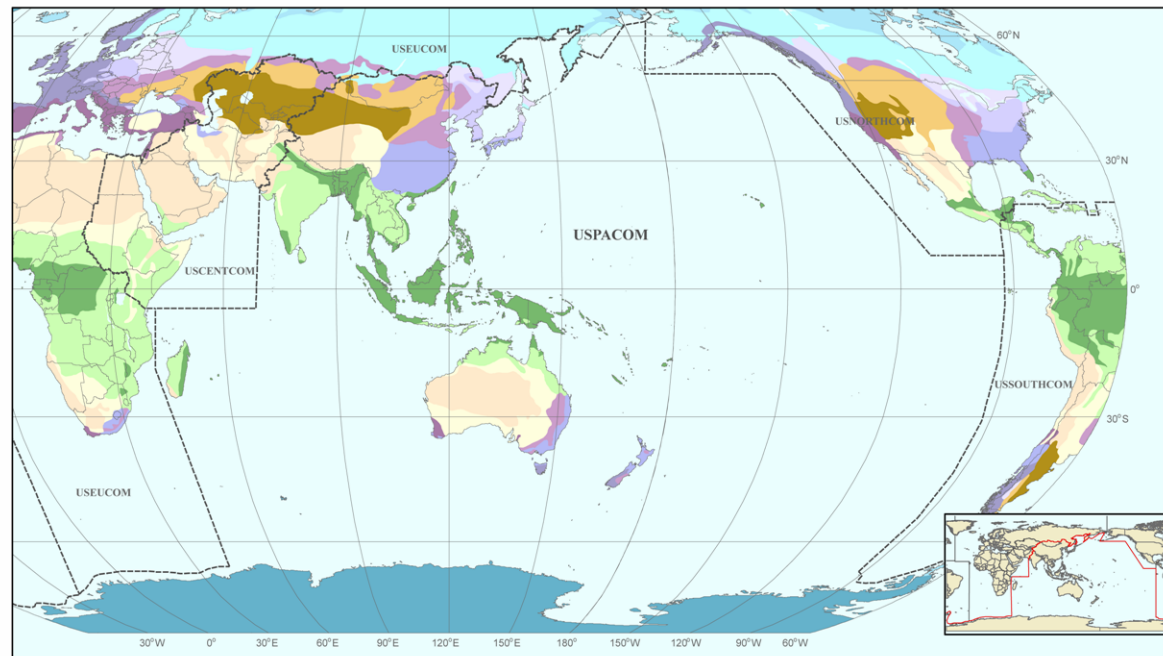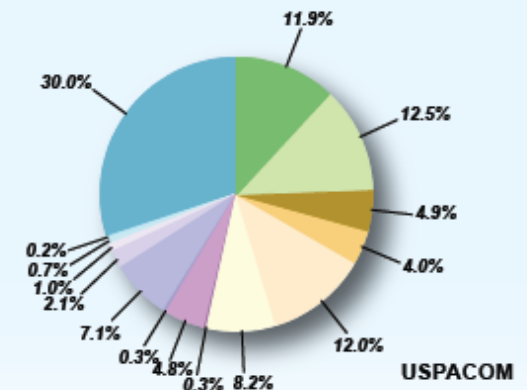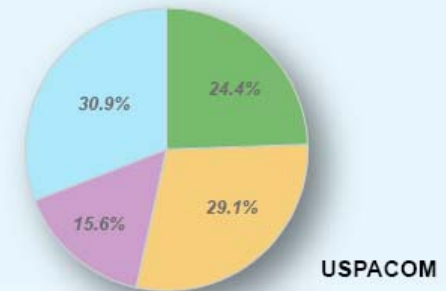
Geographic Distribution of U.S. Army Installations

- **Testing/training and power projection platforms**
- **The scale and spatial distribution of major Army installations are:**
  - **12 million acres in the 50 states (0.5% of U.S. land area)**
  - **30,000 to 2 million contiguous acres of land**
  - **Distributed primarily in the Southeast, Southwest, Western states and Alaska**
  - **Represented by diverse climatic and physiographic regimes/ecosystems**

Global Military Operating Environments - United States

Major Army Installations – Ecoregional Distribution

Global Military Operating Environments - United States

Selected Army Installations
(40 major installations by Ecoregional Division)

Global Military Operational Environments	Major Army Installation Analogs								
Subarctic	Fort Wainwright, AK	Fort Richardson, AK	Donnelly TA, AK						
Warm Continental	Camp Grayling, MI								
Hot Continental	Fort Knox, KY	Fort Benning, GA	Fort Leonard Wood, MO	Fort Campbell, KY	Fort Drum, NY	Camp Ripley, MN	Fort McCoy, WI	Fort Dix, NJ	Camp Atterbury, IN
Subtropical	Aberdeen PG, MD	Fort Bragg, NC	Fort Stewart, GA	Fort Polk, LA	Fort Rucker, AL	Fort Jackson, SC	Fort Gordon, GA	Camp Blanding, FL	Camp Shelby, MS
Marine	Fort Lewis, WA								
Prairie	Fort Riley, KS								
Mediterranean	Fort Hunter Liggett, CA								
Tropical/Subtropical Steppe	Fort Sill, OK	Fort Hood, TX							
Tropical/Subtropical Desert	Fort Irwin, CA	Fort Bliss, TX	Fort Huachuca, AZ	White Sands Missile Range, NM	Yuma Proving Ground, AZ				
Temperate Steppe	Fort Carson, CO	Pinyon Canyon, CO							
Temperate Desert	Yakima Training Ctr, WA	Dugway Proving Ground, UT	Orchard Training Area, ID						
Savanna	Camp Santiago, PR								
Rainforest	Schofield Bks, HI	Pohakuloa Training Area, HI							

Tropical/Subtropical Steppe Environments

Global Military Operating Environments - Tropical/Subtropical Steppe

Dry Domain

Tropical/Subtropical Steppe

9.8%

90.2%
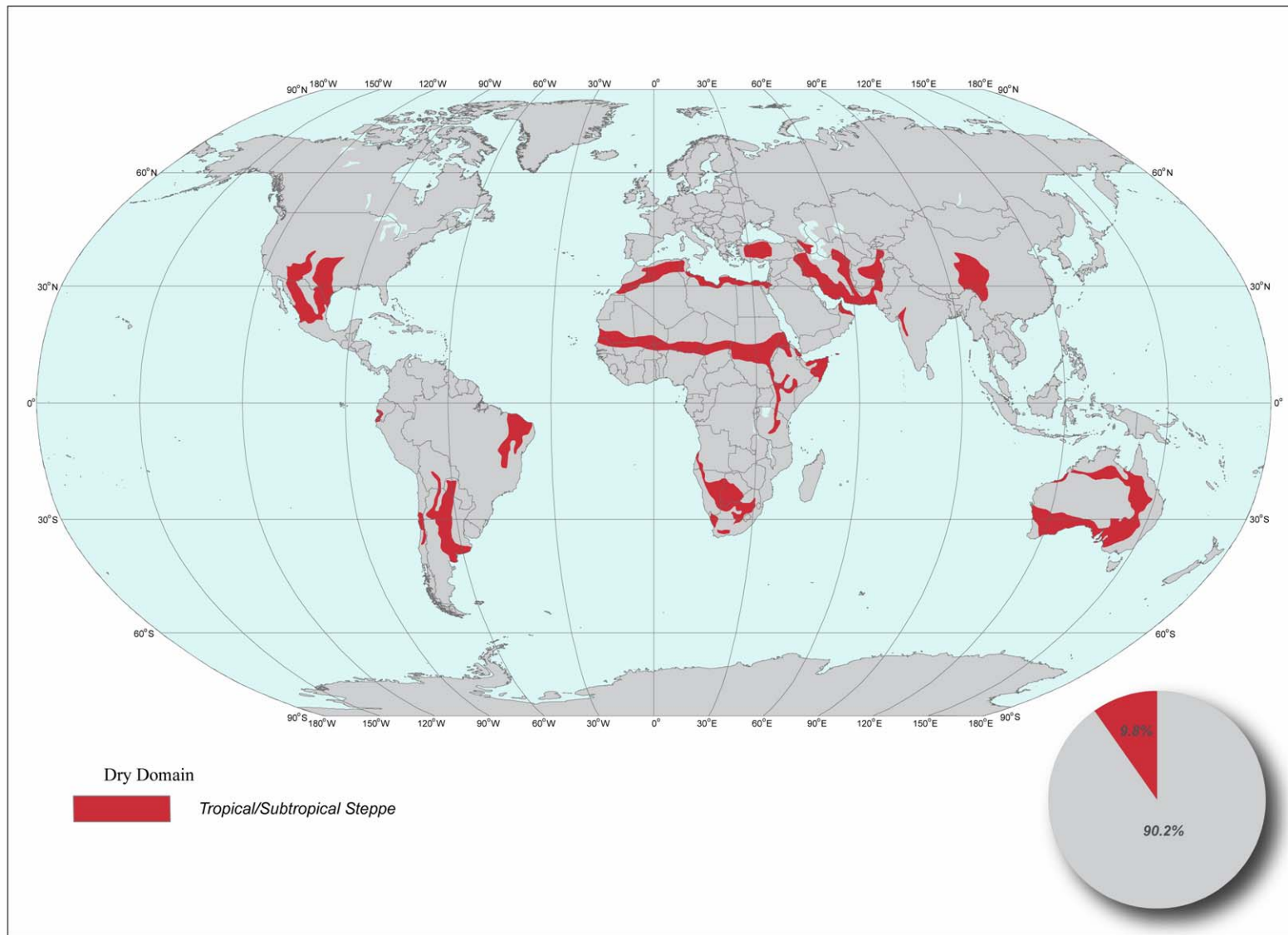
GMOE Climographs – Tropical/Subtropical Steppe

Analog Characteristics

Locations:

• Transition zones that occur along less arid margins of tropical deserts
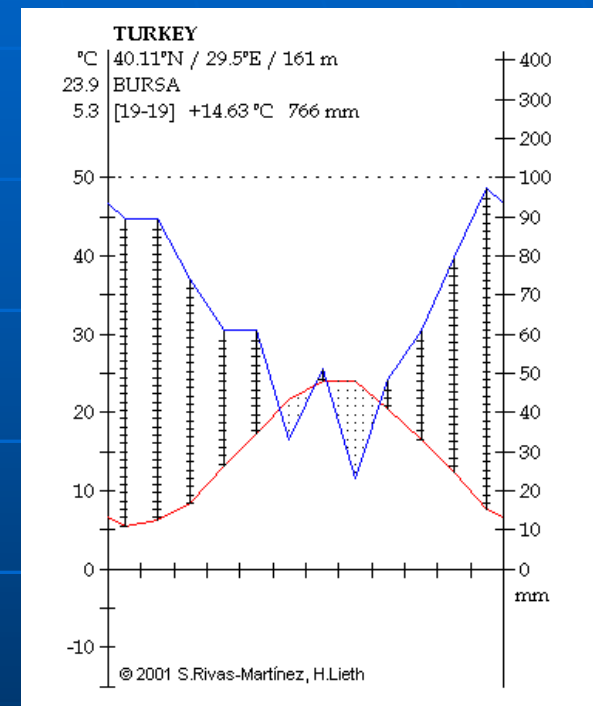
• Influence of higher elevations
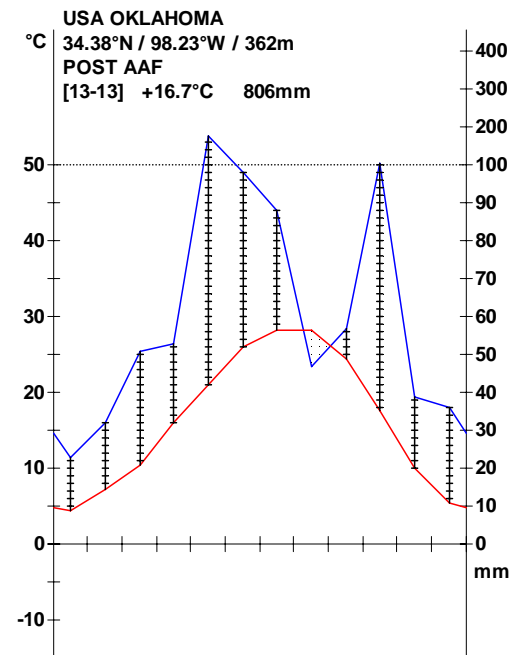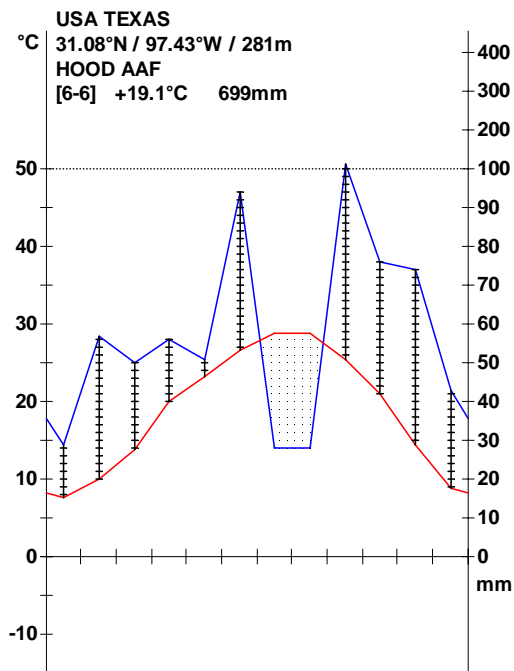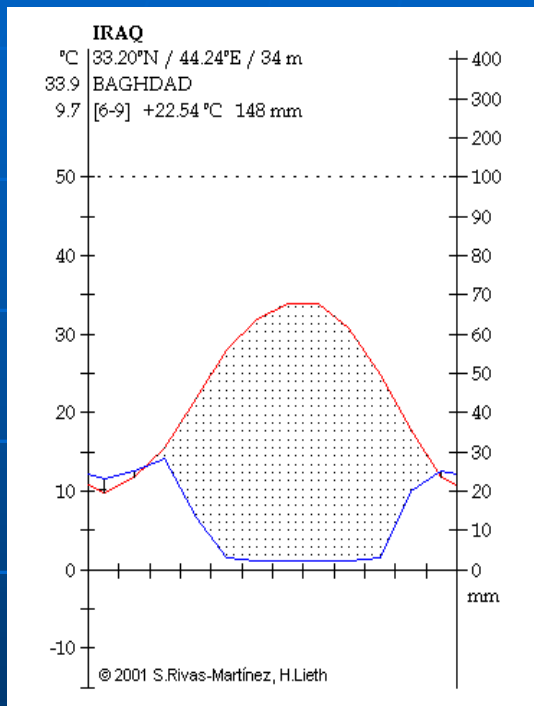
Temperature:

• All months > 0 C

Precipitation:

• Semi-arid, evaporation exceeds precipitation

Vegetation:

• short grasslands, shrubs

Army Installations –
Tropical/Subtropical Steppe Analogs

USA TEXAS
31.08°N / 97.43°W / 281m
HOOD AAF
[6-6] +19.1°C 699mm

USA OKLAHOMA
34.38°N / 98.23°W / 362m
POST AAF
[13-13] +16.7°C 806mm

Tropical/Subtropical Desert Environments

Global Military Operating Environments - Tropical/Subtropical Desert

Dry Domain

Tropical/Subtropical Desert

13.9%

86.1%

GMOE Climographs – Tropical/Subtropical Desert

IRAQ
°C | 33.20°N / 44.24°E / 34 m
33.9 | BAGHDAD
9.7 | [6-9] +22.54 °C 148 mm

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AFGHANISTAN
°C | 31.30°N / 65.51°E / 1010 m
31.8 | QANDAHAR
4.8 | [15-15] +18.4 °C 163 mm

@ 2001 S.Rivas-Martínez, H.Lieth

Analog Characteristics
Locations:
• Vast desert belts associated with 30 N/S latitudes
Temperature:
• High direct solar radiation, highest temps > 30 C
Precipitation:
• Very dry, annual precipitation < 200 mm
Vegetation
• Xerophytic plant formations, drought resistant
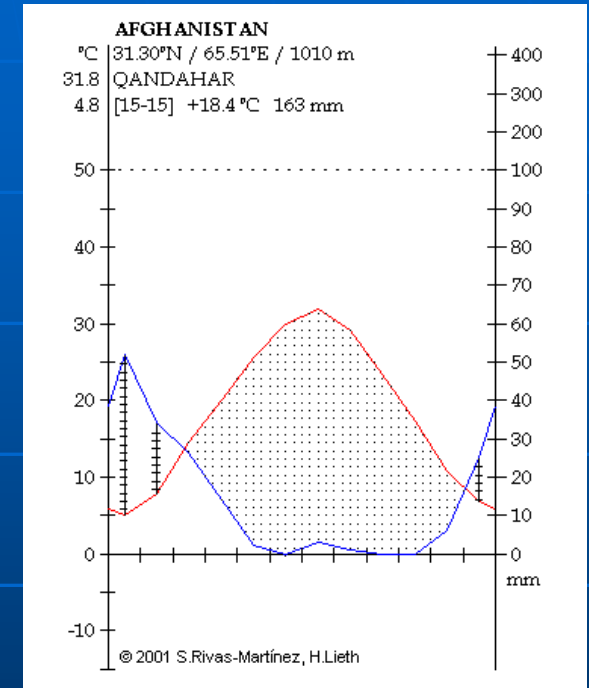
Army Installations – Tropical/Subtropical Desert Analogs

USA CALIFORNIA
35.17°N / 116.37°W / 716m
BICYCLE LAKE AAF
[13-13] +18.4°C   64mm

USA NEW MEXICO
32.50°N / 106.00°W / 1279m
ALAMOGORDO
[53-53] +16.4°C   264mm
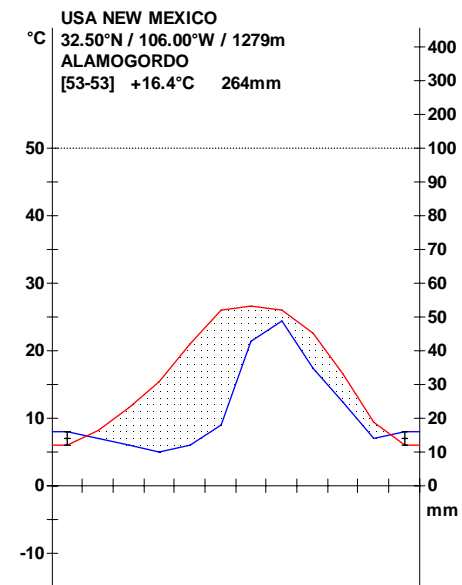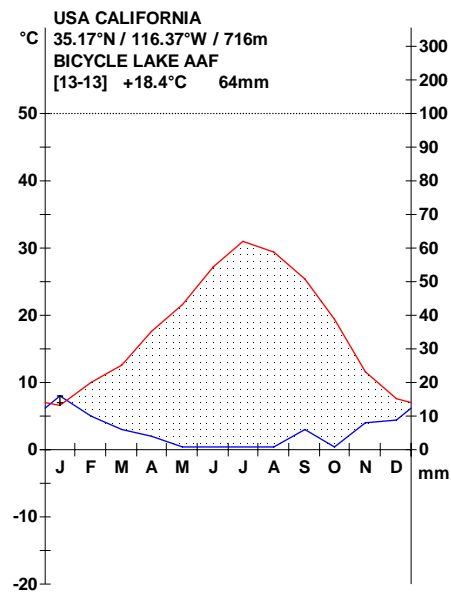
Temperate Steppe Environments

Global Military Operating Environments - Temperate Steppe

GMOE Climographs – Temperate Steppe

CHINA
°C | 40.25°N / 115.30°E / 550 m
25 | HUAI-LAI/AWAILAI
-8.3 [9-11] +9.72 °C 385 mm

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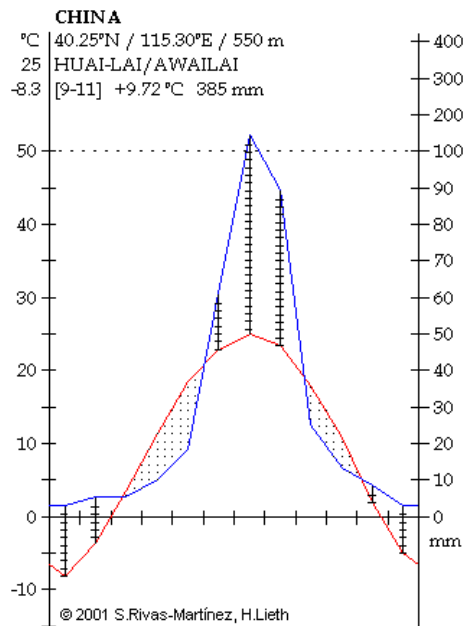
Analog Characteristics

Locations:
- Central, continental locations

Temperature:
- At least one month < 0 C; cold and dry winters, warm summers

Precipitation:
- 300-500 mm annually

Vegetation:
- shortgrass prairie, pampas

KAZAKHSTAN
°C | 49.48°N / 73.8°E / 555 m
20 | KARAGANDA
-15 [30-11] +2.36 °C 338 mm

© 2001 S.Rivas-Martínez, H.Lieth
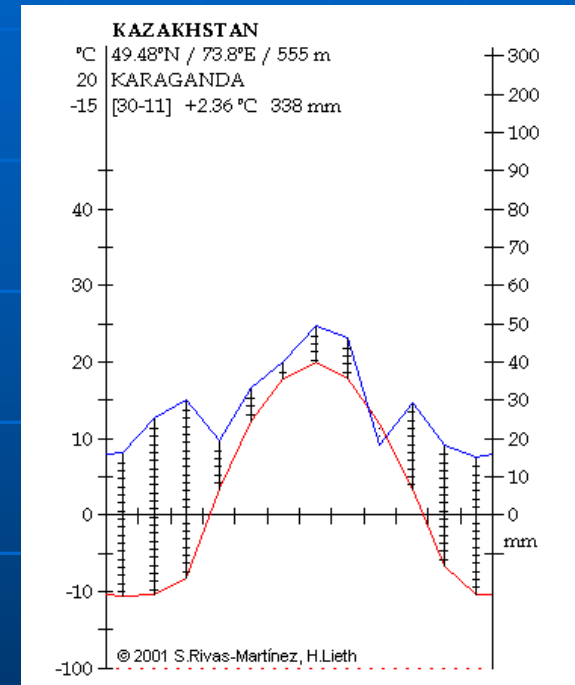
Army Installations –
Temperate Steppe Analogs
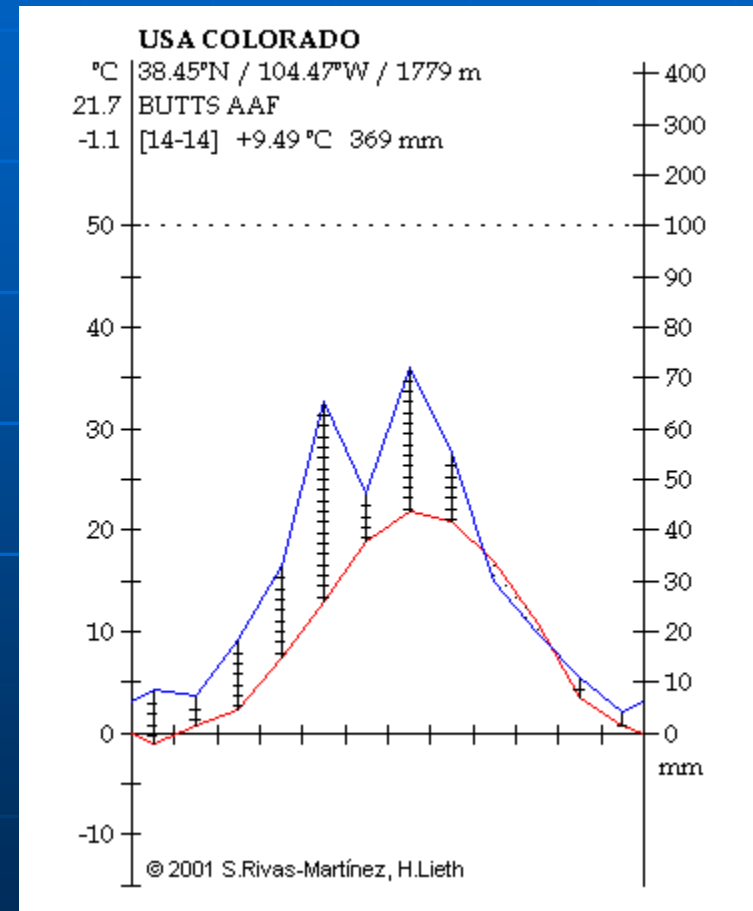
Temperate Desert Environments

Global Military Operating Environments - Temperate Desert
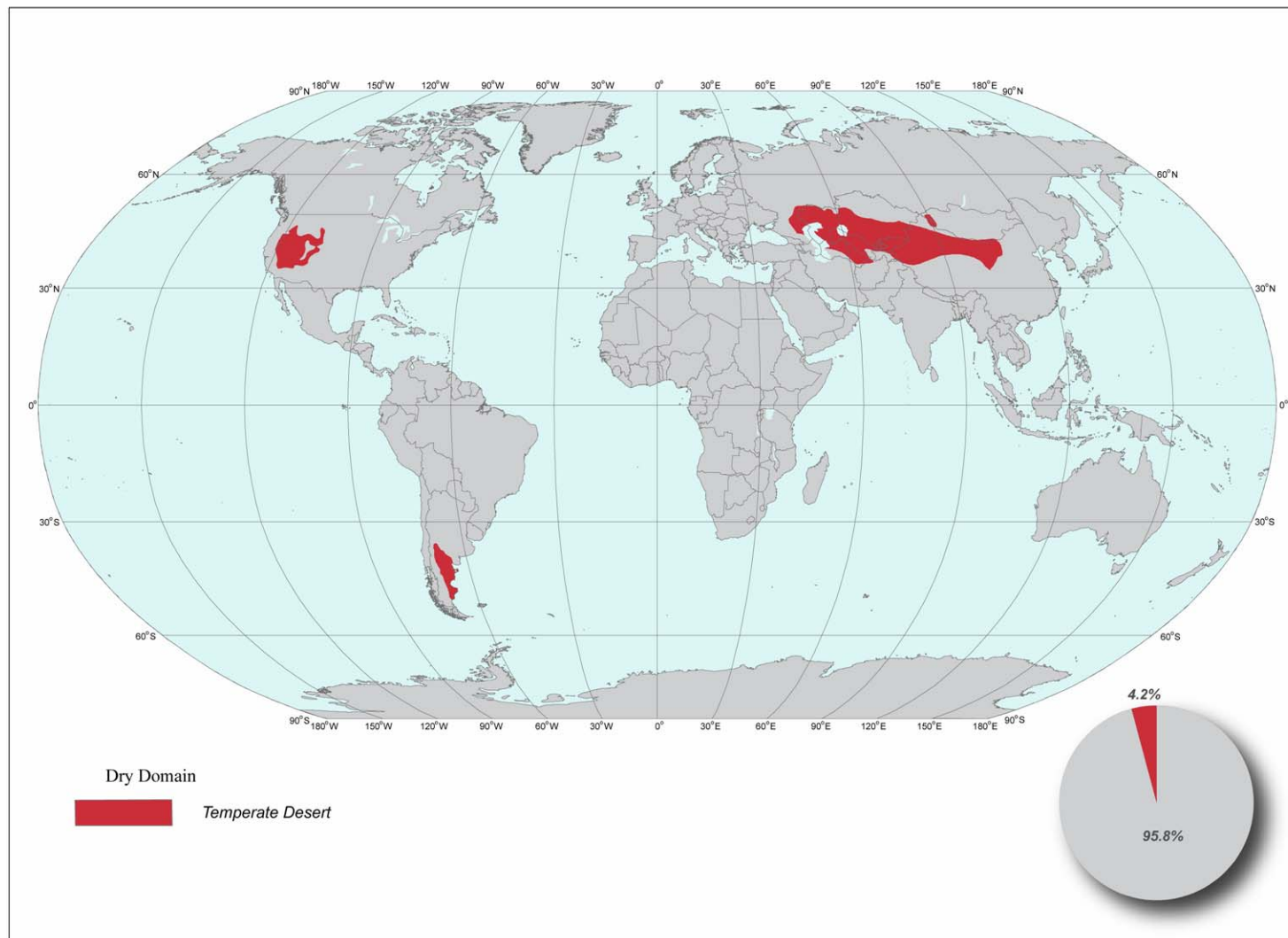
GMOE Climographs – Temperate Desert
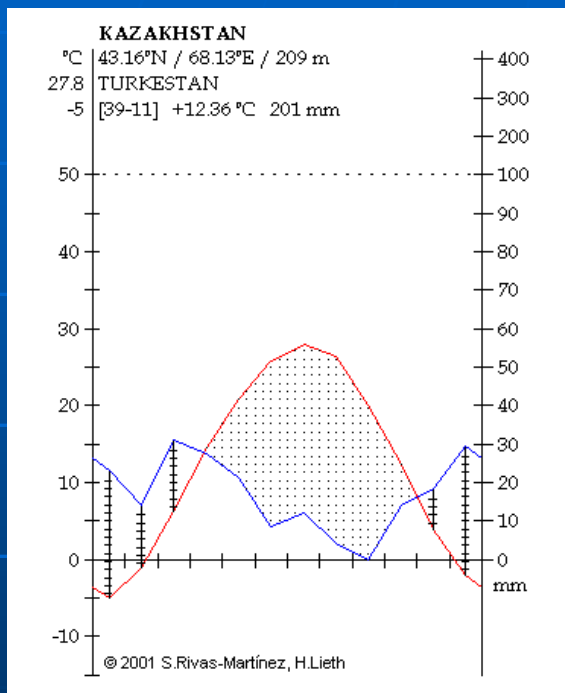
Analog Characteristics
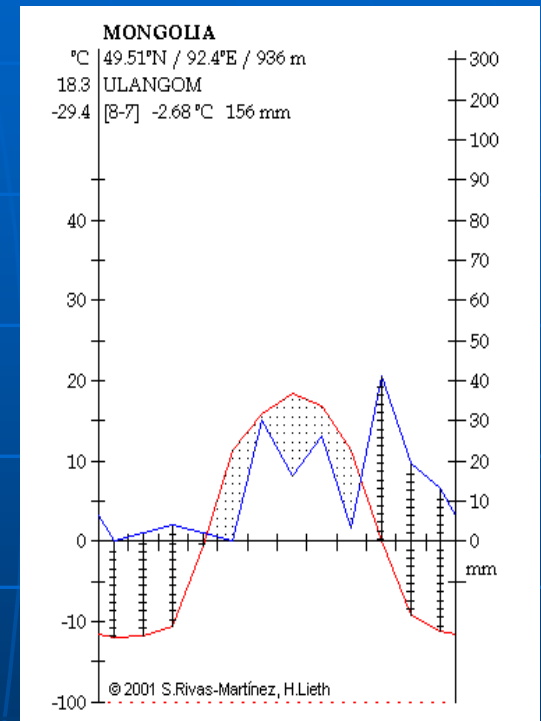Locations:
  • Continental interiors
Temperature:
• Strong contrast between winter and summer
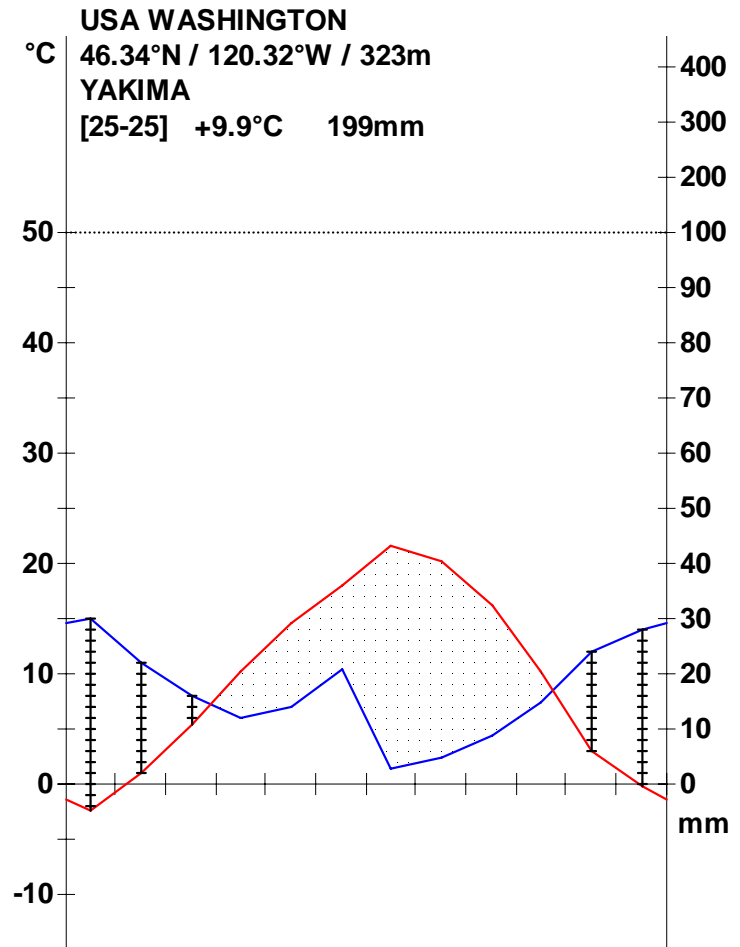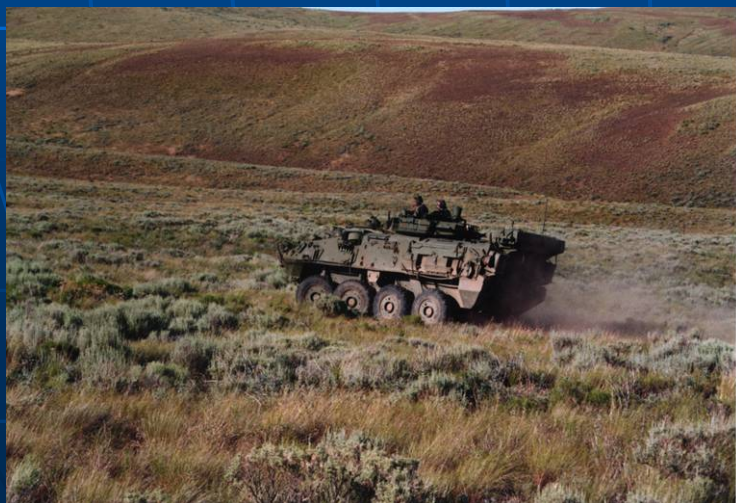• Cold winters, at least one month < 0 C
Precipitation:
• Arid, winter precipitation dominant
Vegetation:
• Sparse, xerophytic shrubs (sagebrush)
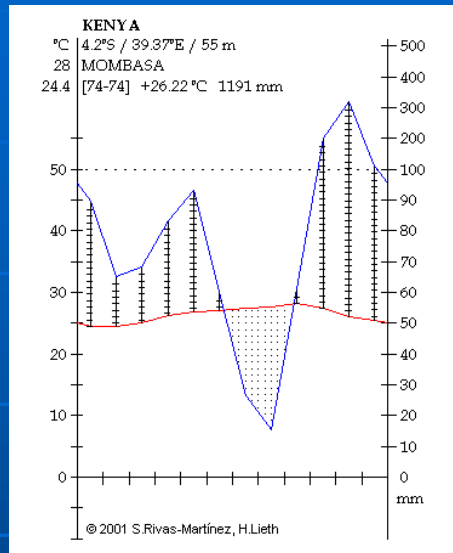
Army Installations – Temperate Desert Analogs

USA WASHINGTON
46.34°N / 120.32°W / 323m
YAKIMA
[25-25]   +9.9°C   199mm

Savanna Environments

Global Military Operating Environments - Savanna
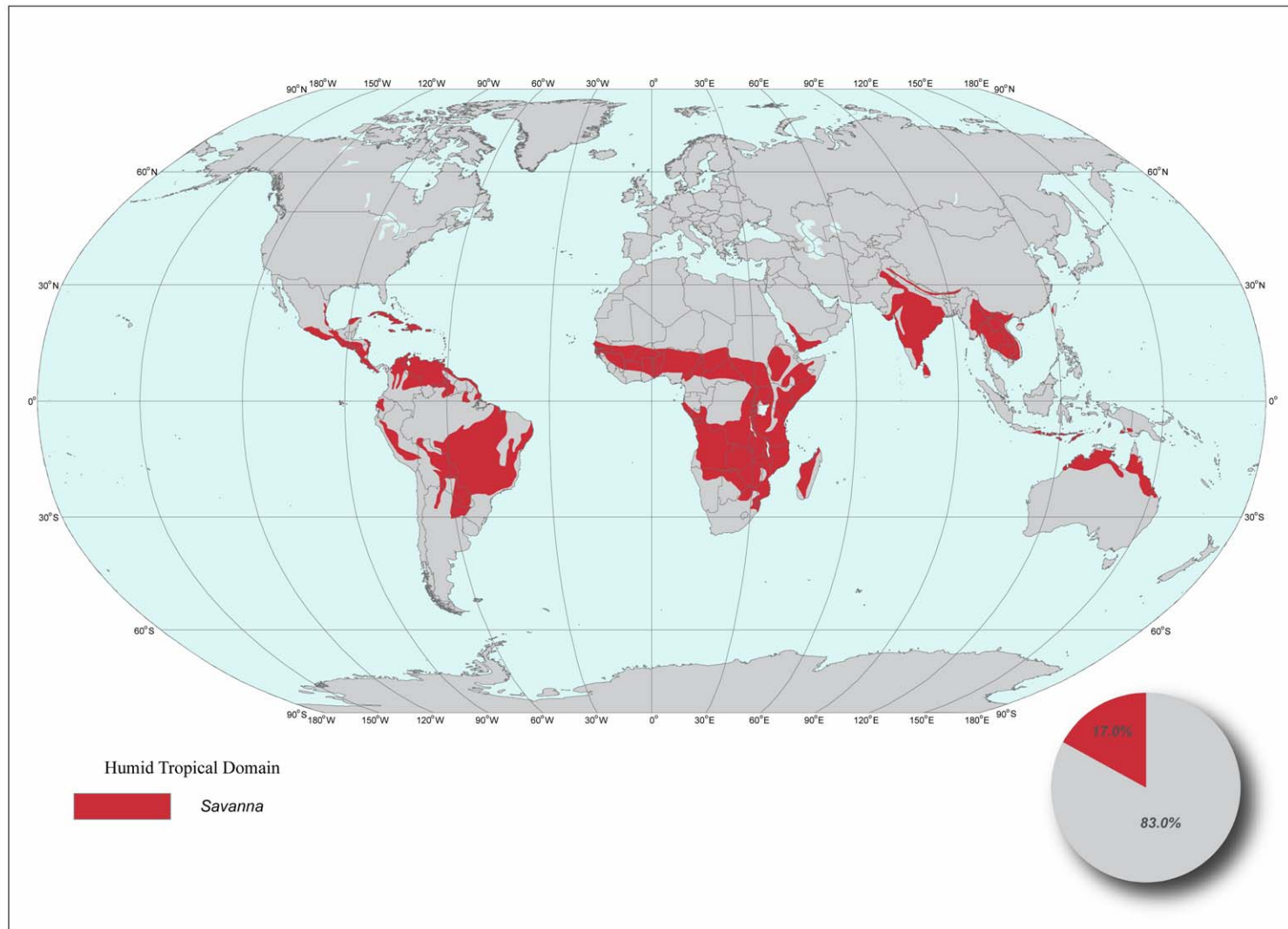
GMOE Climographs - Savanna

KENYA
°C | 4.2°S / 39.37°E / 55 m
28 MOMBASA
24.4 [74-74] +26.22 °C 1191 mm

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HAITI
°C | 18.33°N / 72.19°W / 32 m
28.9 BOWEN HA
25.6 [52-71] +26.99 °C 1353 mm

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Analog Characteristics
Locations:
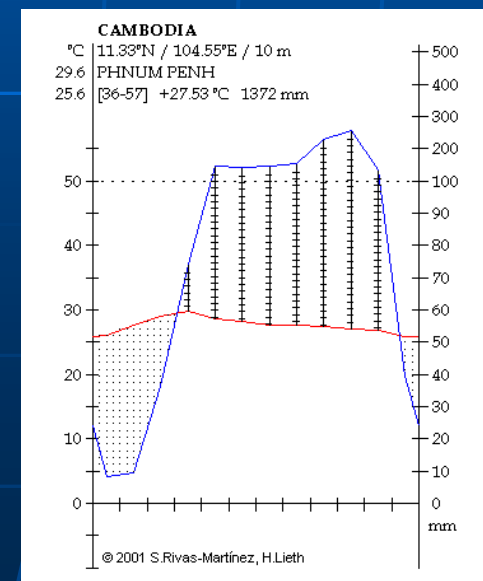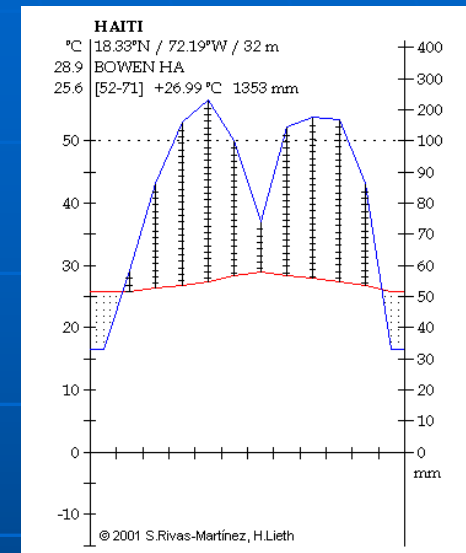• Latitude belt between 10-30 degrees N/S
Temperature:
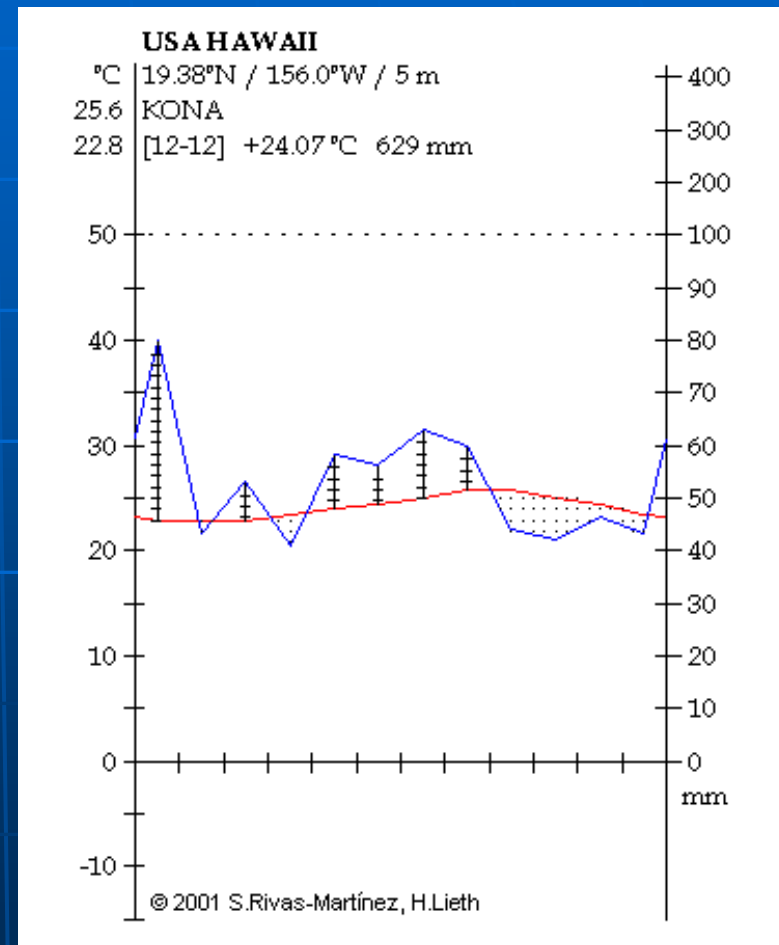• High, constant temperatures > 20 C
Precipitation:
• Alternating wet and dry seasons
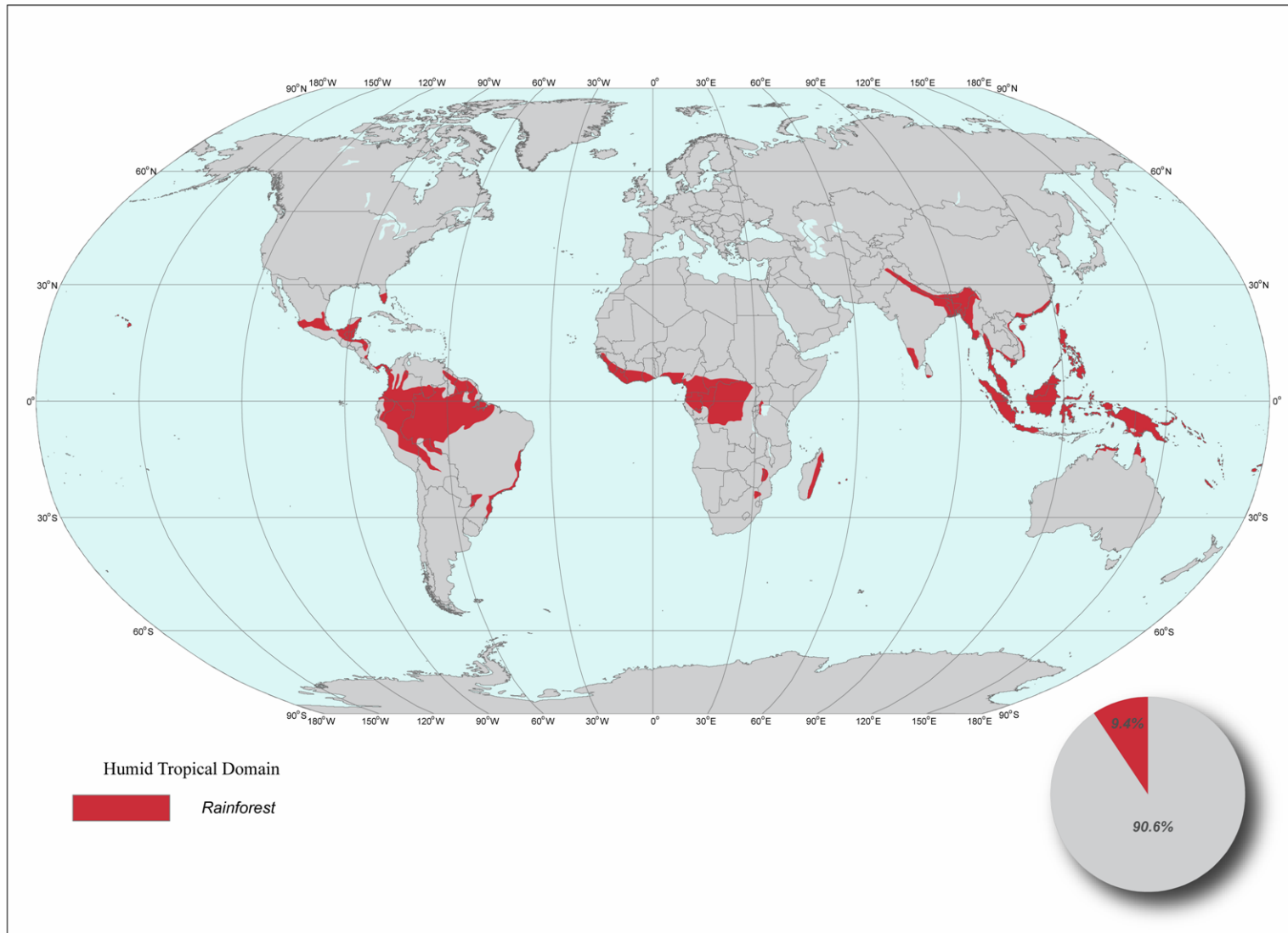**Vegetation:**
• Scrub woodlands, tall grasses

CONGO
°C | 2.31°S / 14.45°E / 791 m
23.9 DJAMBALA
21.7 [5-21] +22.96 °C 1889 mm

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CAMBODIA
°C | 11.33°N / 104.55°E / 10 m
29.6 PHNUM PENH
25.6 [36-57] +27.53 °C 1372 mm

© 2001 S.Rivas-Martínez, H.Lieth
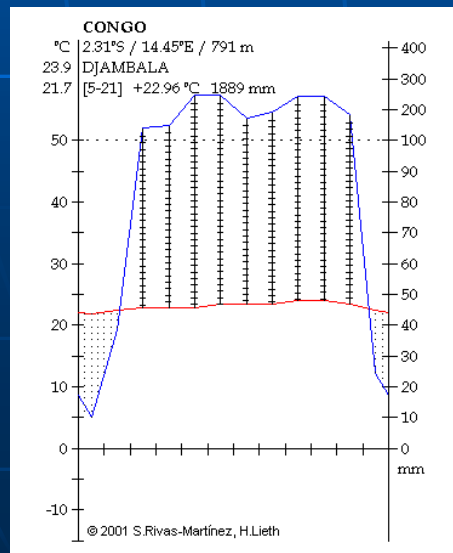
Army Installations – Savanna Analogs

Rainforest Environments

Global Military Operating Environments - Rainforest

Humid Tropical Domain

Rainforest

GMOE Climographs - Rainforest

LIBERIA
°C 6.18°N / 10.45°W / 25 m
27 MONROVIA
24.4 [10-11] +25.74 °C 4624 mm

COLOMBIA
°C 6.13°N / 75.35°W / 1498 m
22.2 MEDELLIN MUNI
21.1 [6-16] +21.62 °C 1490 mm

Analog Characteristics

Locations:

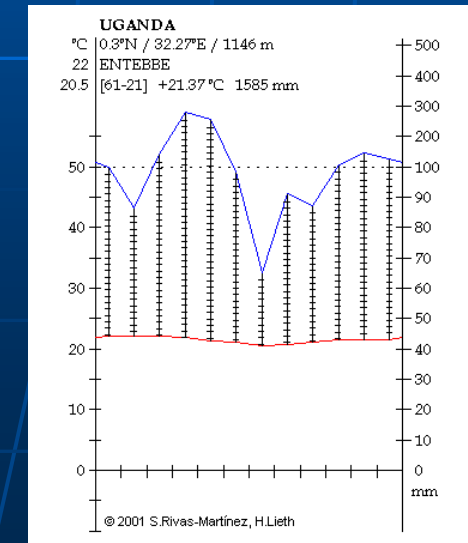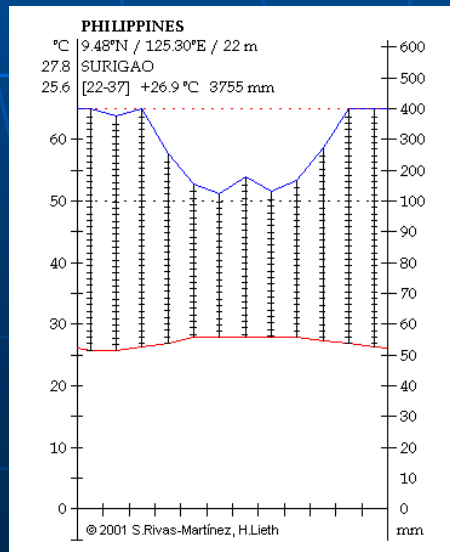- Between equator and Tropics of Cancer/Capricorn (23.5 °N/S)
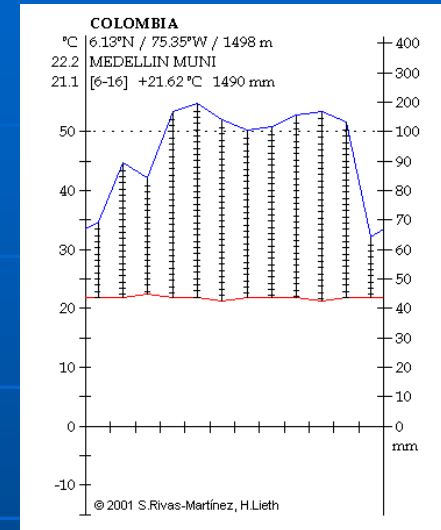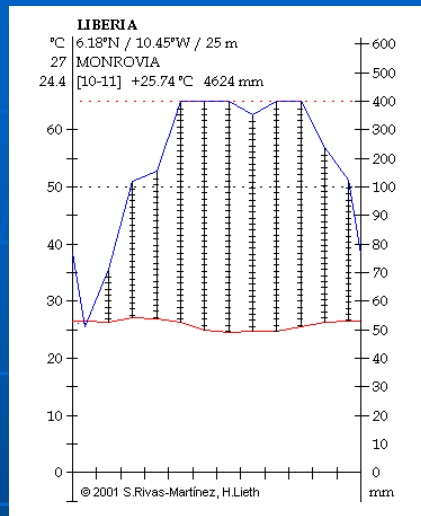
Temperature:

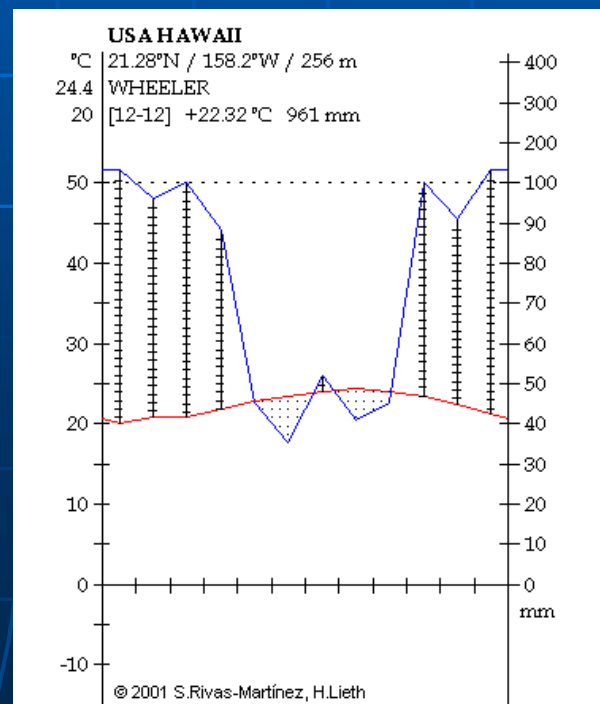- Average monthly temperatures consistently above 18 °C (no winter season)

Precipitation:

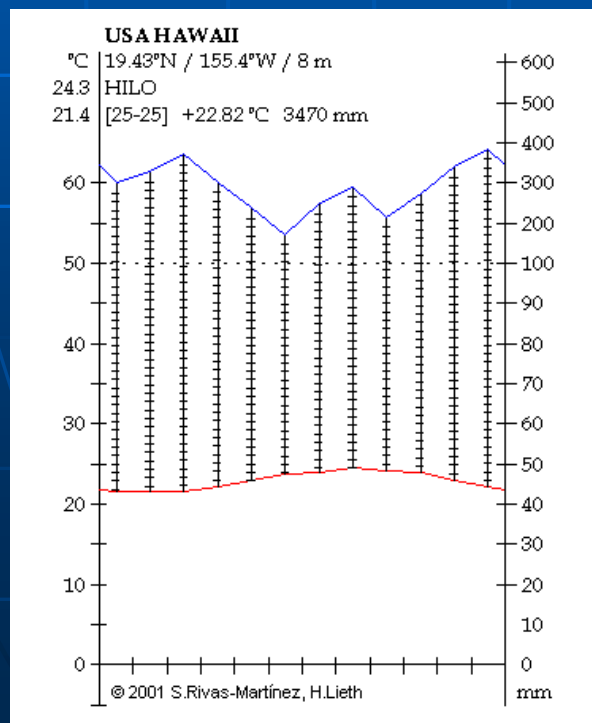- Heavy rainfall amounts generally > 60mm/month

Vegetation:

- Tropical rainforest

PHILIPPINES
°C 9.48°N / 125.30°E / 22 m
27.8 SURIGAO
25.6 [22-37] +26.9 °C 3755 mm

UGANDA
°C 0.3°N / 32.27°E / 1146 m
22 ENTEBBE
20.5 [61-21] +21.37 °C 1585 mm

Army Installation Landscapes – Rainforest Analogs

USA HAWAII
°C | 19.43°N / 155.4°W / 8 m
24.3 | HILO
21.4 | [25-25] +22.82 °C 3470 mm

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USA HAWAII
°C | 21.28°N / 158.2°W / 256 m
24.4 | WHEELER
20 | [12-12] +22.32 °C 961 mm

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Conclusions

- The Global Military Operating Environments (GMOE) framework provides strategic-level, world-wide environmental characterization and analog relationships between Army installations and combatant command geographic regions. At the strategic scale,
- Installation analogs are adequate for:
  - Humid temperate environments
  - Dry environments
- Installation analogs are inadequate for:
  - Humid tropical environments
- More detailed studies using available digital data at high resolution are needed to compare areas within specific installation analogs to operational areas of concern